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SIMULATED ALTITUDE PERFORMANCE OF MARK 11 REENTRY VEHICLE SPIN AND PITCH MOTORS HAVING AGES FROM 37 TO 102 MONTHS

R. M. Brooksbank

ARO, Inc.

December 1971

ENGINE TEST FACILITY

ARNOLD ENGINEERING DEVELOPMENT CENTER

AIR FORCE SYSTEMS COMMAND

ARNOLD AIR FORCE STATION, TENNESSEE

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(UNCLASSIFIED REPORT)

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Arnold Engineering Development Center
Air Force Systems Command
Arnold Air Force Station, Tennessee

Table IIc (page 53) and Table IIIa (page 55) are to be replaced with the corrected tables printed on this sheet.

TABLE II (Continued)
c. ARC Mark 11B/11C 0.5-KS-30 Pitch Motors (P/N 331121-1)

Motor Type	Specification Limits, ohms	0.5-KS-30								
Motor Serial Number		0605869	0605894	0605897	0605899	0605901	0605902	0605153	0606073	0606076
Date of Manufacture		10/66	11/66	11/66	11/66	11/66	11/66	5/66	5/67	5/67
Motor Age, months		57	56	56	56	56	56	52	50	50
Test Date		7/8/71	7/8/71	7/8/71	7/14/71	7/14/71	7/14/71	7/24/71	7/24/71	7/24/71
Prefire Ignition System Resistance, ohms										
Pins A to F (Squib No. 1)	0.16 to 0.22	0.21	0.22	0.20	0.22	0.20	0.20	0.20	0.22	0.17
Pins B to C (Squib No. 2)	0.16 to 0.22	0.21	0.21	0.20	0.21	0.21	0.21	0.20	0.22	0.18
Pins D to E (Fuse)	0.02 to 0.10	0.09	0.09	0.10	0.09	0.09	0.09	0.08	0.03	0.1
Shorted Pins AF to Shorted Pins BC	>10 meg	175 meg	200 meg	2,000 meg	1,000 meg	200 meg	400 meg	80 meg	175 meg	200 meg
Shorted Pins AF to Shorted Pins DE	>10 meg	150 meg	200 meg	2,000 meg	1,000 meg	175 meg	400 meg	90 meg	150 meg	200 meg
Shorted Pins BC to Shorted Pins DE	>10 meg	150 meg	200 meg	2,000 meg	1,000 meg	175 meg	400 meg	90 meg	175 meg	200 meg
Prefire Case Insulation Resistance, ohms										
Pins A, B, C, D, E, and F to Motor Case	>10 meg	125 meg	125 meg	600 meg	600 meg	175 meg	200 meg	90 meg	125 meg	200 meg

TABLE III
SUMMARY OF MOTOR PERFORMANCE
a. ARC Mark 11B/11C Spin Motors (P/N 331120-1)

Motor Type	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30
Motor Serial Number	0705735	0705736	0705932	0705933	0705732	0706393	0705700	0705566	0706072
Test Number	07	08	09	10	11	12	13	14	15
Date of Manufacture	10/66	10/66	11/66	11/66	10/66	6/68	5/66	10/66	5/67
Test Date	7/14/71	7/14/71	7/14/71	7/15/71	7/15/71	7/15/71	7/21/71	7/21/71	7/21/71
Motor Age, months	59	57	56	56	57	37	62	57	50
Motor Case Temperature at Ignition, °F	103	102	100	102	101	100	100	99	99
Simulated Altitude at Ignition, ft	146,000	147,000	147,000	146,000	146,000	146,000	144,000	149,000	149,000
Thrust Delay Time (t_d), msec[1]	4	2	3	3	2	3	2	2	2
Ignition Delay Time (t_i), msec[2]	4	2	3	3	2	3	2	2	2
Thrust Action Time (t_{at}), sec[3]	0.713	0.717	0.705	0.683	0.716	0.707	0.693	0.752	0.733
Burn Time (t_b), sec[4]	0.685	0.690	0.678	0.657	0.691	0.678	0.670	0.722	0.705
Full-Duration Burn Time (t_{fb}), sec[5]	0.765	0.770	0.750	0.728	0.790	0.765	0.740	0.795	0.780
Measured Total Impulse (Based on t_{fb}), lbf-sec (Not Weight Corrected)	29,375	29,010	29,246	29,325	29,281	29,361	29,358	28,960	28,555
Number of Channels Averaged	2	1	2	2	2	2	2	2	1
Maximum Deviation from Average, percent	0.11	---	0.02	0.08	0.04	0.00	0.10	0.16	---
Cell Pressure Integral (Based on t_{fb}), psia-sec	0.02726	0.02781	0.02529	0.02722	0.02719	0.02788	0.02881	0.02677	0.02705
Number of Channels Averaged	3	3	3	3	3	3	3	3	3
Maximum Deviation from Average, percent	0.4	0.5	0.9	1.1	0.4	0.4	0.3	0.4	0.5
Average Simulated Altitude during t_{fb}, ft	136,000	137,000	136,000	136,000	136,000	136,000	135,000	138,000	138,000
Vacuum Total Impulse (based on t_{fb}) lbf-sec (Weight Corrected)	29,438	29,073	29,307	29,386	29,342	29,424	29,419	29,024	28,618
Expended Mass (AEDC Measured Prefire and Postfire Weight Difference, Including Nozzle Closure), lbm	0.1328	0.1328	0.1326	0.1348	0.1328	0.1332	0.1336	0.1334	0.1339
Manufacturer's Stated Nominal Propellant Weight, lbm	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130
Vacuum Specific Impulse (Based on Weight Corrected Vacuum Total Impulse over t_{fb} and Manufacturer's Stated Nominal Propellant Weight) lbf-sec/lbm	226.4	223.6	225.4	226.0	225.7	226.3	226.3	223.3	220.1

[1]Interval from zero time to time of increase in thrust (where zero time is the time of application of ignition current).

[2]Time interval between zero time and the time that thrust has reached 10 percent of maximum during ignition (excluding ignition spike).

[3]Time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and 10 percent of maximum thrust during tailoff.

[4]Time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and the return of thrust to 75 percent of maximum during tailoff.

[5]Interval from time of increase in thrust during ignition to time that thrust has decreased to zero during tailoff.

SIMULATED ALTITUDE PERFORMANCE OF MARK 11 REENTRY VEHICLE SPIN AND PITCH MOTORS HAVING AGES FROM 37 TO 102 MONTHS

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ARO, Inc.

FOREWORD

The test program reported herein was conducted at the request of Ogden Air Materiel Area (OOAMA)(MMEMP), Hill Air Force Base, Utah, for Headquarters, Strategic Air Command (SAC)(DM7B), under Program Element 11213F, System 133B.

The results of the test were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), Arnold Air Force Station, Tennessee, under Contract F40600-72-C-0003. The test was conducted in Propulsion Development Test Cell (T-3) of the Engine Test Facility (ETF) from July 8 to 30, 1971, under ARO Project Number RC0181, and the manuscript was submitted for publication on October 15, 1971.

This technical report has been reviewed and is approved.

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ABSTRACT

Twenty Atlantic Research Corporation (ARC) pitch motors (0.5-KS-30) (9 of P/N 331121-1 and 11 of P/N 330198-1) and twenty ARC spin motors (1-KS-30)(9 of P/N 331120-1 and 11 of P/N 330130-1) were subjected to prescribed nondestructive sinusoidal vibration, temperature cycling (from -35 to +125°F), and electrical resistance measurements and tested at pressure altitudes ranging from 135,000 to 141,000 ft to investigate the possibility of extending the service life of the motors. The ages of the motors ranged from 37 to 102 months. Two of the spin motors failed at ignition, resulting in case rupture and ejection of the propellant grain.

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NOMENCLATURE

F_{max}	Maximum thrust, the highest thrust developed during a motor firing, excluding ignition spike
t_{at}	Thrust action time, time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and 10 percent of maximum thrust during tailoff, sec
t_b	Burn time, time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and 75 percent of maximum thrust during tailoff, sec

t_d	Thrust delay time, interval from zero time to time of increase in thrust, msec
t_{fb}	Full-duration burn time, interval from time of increase in thrust during ignition to time that thrust has decreased to zero during tailoff, sec
t_i	Ignition delay time, time interval between zero time and time that thrust has reached 10 percent of maximum during ignition (excluding ignition spike), msec
t_o	Zero time, time at which firing voltage is applied to the igniter circuit, msec

SECTION I
INTRODUCTION

The Atlantic Research Corporation (ARC) spin (1-KS-30) and pitch (0.5-KS-30) solid-propellant rocket motors are used in the attitude control system of the Mark 11/11A and 11B/11C Reentry Vehicles (Weapons System 133B)(Refs. 1 and 2). Spin motors (P/N 330130-1) and pitch motors (P/N 330198-1) are used for the Mark 11/11A, while spin motors (P/N 331120-1) and pitch motors (P/N 331121-1) are used for the Mark 11B/11C Reentry Vehicle (Ref. 3). The Mark 11B/11C motors are identical to the Mark 11/11A version except for a change in the igniter squib, a slight shortening of the motor case, and a modification to the igniter connector.

To obtain data necessary to determine the possibility of extending the service life of the motors, a series of tests set forth in Model Specification S-133-1005-0-1-5 (P/N 330198-1)(Ref. 4), S-133-1005-0-1-6 (P/N 330130-1)(Ref. 5), S-133-1005-32 (P/N 331121-1)(Ref. 6), and S-133-1005-33 (P/N 331120-1)(Ref. 7) was performed. These tests encompassed prefire motor non-destructive vibration tests (performed at the AEDC only on motors P/N 331121-1 and 331120-1), temperature cycling, and motor and igniter electrical resistance tests, followed by temperature conditioning and firing the motors at simulated altitude conditions to determine ballistic performance. The prefire nondestructive tests were performed at AEDC on all motors (except for the vibration tests for motors P/N 330198-1 and 330130-1, which had been previously conducted at Hill AFB).

The altitude ballistic performance and igniter squib, fuse, and case insulation resistances are discussed and compared with the ranges set forth in the model specifications. The ages of the motors tested during this program ranged from 37 to 102 months.

Motor ignition characteristics, altitude ballistic performance, and structural integrity are presented and discussed. Previous testing of motors of similar design having ages ranging from 24 to 71 months is described in Refs. 8 through 17; a comparison of current test results with previous test results is made in Section IV of this report.

SECTION II
APPARATUS

2.1 TEST ARTICLE

The ARC 1-KS-30 full-scale, flightweight, solid-propellant spin motor (Fig. 1, Appendix I) is 1.53 in. in diameter and 9.77 in. (9.58 in. for P/N 331120-1) in length, including the 4.88-in.-long blast tube bonded to the motor case. The motor case is made of 0.040-in.-thick, 4130 normalized steel. The 27° 30', half-angle, conical nozzle has a graphite throat insert with a nominal throat area of 0.0252 $in.^2$. The expansion ratio (ratio of blast-tube exit area to nozzle throat area) is 17.8:1. A silicone rubber nozzle closure was used to seal the chamber at sea-level pressure conditions. The total weight of the loaded motor is 1.059 lbm, of which approximately 0.130 lbm is Arcite® 362M propellant.

The ARC 0.5-KS-30, full-scale pitch motor (Fig. 2) is 1.25 in. in diameter and 6.09 in. in length (5.91 in. for P/N 331121-1), including the 1.45-in.-long blast tube bonded to the motor case. The motor case is made of 0.030-in.-thick, 4130 normalized steel. The pitch motor incorporates a 27° 30', half-angle, conical nozzle made of 4130 steel with a nominal throat area of 0.0206 $in.^2$. The expansion ratio (ratio of blast tube exit area to nozzle throat area) of the 0.5-KS-30 pitch motor is 21.6:1. A silicone rubber closure was used to seal the chamber at sea-level pressure conditions. The total weight of the loaded pitch motor is 0.800 lbm, of which approximately 0.069 lbm is Arcite 377A propellant.

The 1-KS-30 spin motors and the 0.5-KS-30 pitch motors utilize an internal-external burning, cylindrically perforated propellant grain (ICC Class B), cantilever bonded to the front of the motor chamber.

Nominal performance for the 1-KS-30 motor at 70°F is: thrust, 40 lbf; chamber pressure, 1100 psia; specific impulse, 225 lbf-sec/lbm; and thrust action time (t_{at}), 0.753 sec. Nominal performance for the 0.5-KS-30 motor at 70°F is: thrust, 34 lbf; specific impulse, 228 lbf-sec/lbm; and t_{at}, 0.513 sec.

The Mark 11/11A motors (P/N 330130-1 and 330198-1) incorporate two U. S. Flare 207A squibs while the Mark 11B/11C motors (P/N 331120-1 and 331121-1) incorporate two U. S. Flare ES-003 squibs. These squibs are used to activate igniter charges of 1.5 gm (1-KS-30) and 0.85 gm (0.5-KS-30) of boron pellets located in the front of the

combustion chamber. However, only one squib was used for each motor reported herein. Nominal ignition current is 5 amp. For the Mark 11/11A motors, the igniter connector is attached to the motor by a 12-in.-long electrical cable. The connector for the Mark 11B/11C motors is flush-mounted to the motor, thus eliminating the cable.

2.2 INSTALLATION

The motors were tested in Propulsion Engine Test Cell (T-3) (Ref. 18). Schematics and a photograph of a typical motor installation are shown in Fig. 3. Three motors were installed and fired sequentially during each test period. The motors were mounted on individual load cells, which were supported on a steel base plate, and were fired in the vertical position. The T-3 temperature conditioning system (Ref. 18) was utilized to provide a cell temperature environment of 105°F (for the Mark 11B/11C motors) and 70°F (for the Mark 11/11A motors).

Pressure altitude conditions were maintained in the test cell by a steam ejector operating in series with the ETF exhaust gas compressors. The motor exhaust gas flow and burn time were sufficiently small that an exhaust diffuser was not required.

2.3 INSTRUMENTATION

Instrumentation was provided to measure axial thrust, test cell pressure, and motor case and test cell temperature. Table I (Appendix II) presents instrument ranges, recording methods, and an estimate of measurement uncertainty for all measured parameters.

Axial thrust was measured from low-range (0- to 100-lbf), double-bridge, strain-gage-type load cells. Unbonded strain-gage-type transducers were used to measure test cell pressure. Iron-constantan thermocouples were bonded to the motor case to measure outer surface temperatures.

The output signal of each measuring device was recorded on independent instrumentation channels. Primary data were obtained from two axial thrust channels (per motor) and three test cell pressure channels. These data were recorded as follows: Each instrument output signal was indicated in totalized digital form on a visual readout of a millivolt-to-frequency converter. A magnetic tape system, recording in frequency form, stored the signal from the converter for reduction at a later time by an electronic digital computer. The computer provided

a tabulation of average absolute values for each 0.050-sec time increment and total integrals over the cumulative time increments.

A photographically recording, galvanometer-type oscillograph, recording at a paper speed of 16 in./sec, provided an independent backup of all primary data systems. Motor case temperatures and selected channels of thrust and pressure were recorded on null-balance, potentiometer-type strip charts for analysis immedately after the motor firing. High-speed, motion-picture cameras provided a permanent visual record of the firings.

2.4 CALIBRATION

The thrust load cells and pressure transducers used during the test program were laboratory calibrated prior to use. All transducers and system calibrations performed during this test program are traceable to the National Bureau of Standards (NBS). Each link in the traceability chain back to the NBS is maintained and documented by the AEDC Standards Laboratory. After installation of the measuring devices in the test cell, all systems were calibrated at sea-level ambient conditions and again at simulated altitude conditions just before the motor firing. The pressure systems were calibrated by an electrical, four-step calibration, using resistances in the transducer circuits to simulate selected pressure levels. The axial thrust instrumentation systems were calibrated in a like manner, using resistances to simulate selected force levels of 19, 38, 57, and 76 lbf.

After the final motor firing in a test period and with the test cell still at simulated altitude pressure, the systems were again recalibrated to determine any shift.

SECTION III
PROCEDURE

The 40 motors (twenty ARC 1-KS-30 spin motors, and twenty ARC 0.5-KS-30 pitch motors) arrived at the AEDC on June 7 and 28, 1971, and were visually and radiographically inspected for possible shipping damage. The prefire inspections revealed all motors to be satisfactory except for spin motors S/N 0700043 and 0700097. These two motors were severely corroded internally and did not incorporate a properly placed silicone rubber nozzle throat plug. The motor identification labels on pitch motors S/N 0600196 and 0600198 and spin motor S/N 0700097 were found to be partially detached. During storage in an

area temperature conditioned at 70 ± 5°F, the electrical resistance of each igniter was measured to ensure circuit continuity, the blast tube exit diameters were measured, and each motor assembly was weighed. A silicone rubber nozzle throat closure (factory installed) sealed the chamber of each motor (except for spin motors S/N 0700043 and 0700097, see Section 4.4) to improve ignition characteristics in a near-vacuum environment. Measurements of the throat could not be made because of the presence of the throat closure and blast tube.

The rocket motors were subjected to the following temperature environment cycling as prescribed by motor Model Specifications (Refs. 4 through 7):

1. From ambient to +125 ± 5°F in 4 hr
2. Remain at +125 ± 5°F for a 72-hr soak period
3. From +125 ± 5°F to -35 ± 5°F in 4 hr
4. Remain at -35 ± 5°F for a 72-hr soak period
5. From -35 ± 5°F to +70 ± 5°F in 2 min
6. Remain at +70 ± 5°F for an 8-hr soak period

After the temperature cycling sequence, the prefire nondestructive vibration testing was performed on the Mark 11B/11C motors (nine spin motors, P/N 331120-1, and nine pitch motors, P/N 331121-1) in accordance with the requirements of Ref. 3. (The Mark 11/11A motors had previously been vibration tested at Hill AFB.) Each of these motors was exposed to a 3.5g rms (limited to 0.4-in. double amplitude) sinusoidal vibration in the frequency range from 10 to 2000 Hz, input at the motor mounting flange at a rate of one-half octave each minute for each of the three perpendicular axes (Fig. 4). The tests used the vibrational equipment shown in Fig. 5 and were completed on July 16, 1971.

After the temperature cycling and vibration sequences, the motor electrical systems (Fig. 6) were subjected to electrical resistance tests (Refs. 4 through 7) as follows:

Component	Pins	Required Resistance, Ohms
Squib No. 1	A to F	0.16 to 0.28 (Mark 11/11A); 0.16 to 0.22 (Mark 11B/11C)
Squib No. 2	B to C	0.16 to 0.28 (Mark 11/11A); 0.16 to 0.22 (Mark 11B/11C)
Igniter Fuse	D to E	0.02 to 0.10

Insulation

Squib No. 1 to Squib No. 2	Shorted Pins AF to Shorted Pins BC	>10,000 (Mark 11/11A); >10 meg (Mark 11B/11C)
Squib No. 1 to Igniter Fuse	Shorted Pins AF to Shorted Pins DE	>10,000 (Mark 11/11A); >10 meg (Mark 11B/11C)
Squib No. 2 to Igniter Fuse	Shorted Pins BC to Shorted Pins DE	>10,000 (Mark 11/11A); >10 meg (Mark 11B/11C)
Squib to Motor Case	Shorted Pins A, B, C, D, E, and F to Motor Case	>10,000 (Mark 11/11A); >10 meg (Mark 11B/11C)

The results of these tests are presented in Section IV.

After the nondestructive vibration, temperature cycling, and resistance tests, the motors were again subjected to a radiographic inspection, which revealed no change from the initial preconditioning X-rays. The Mark 11/11A motors (P/N 330130-1 and 330198-1) were stored in an area temperature conditioned at 70 ± 2°F for periods greater than 24 hr prior to a motor firing. The time after removal of the motors from the temperature-conditioning unit until the motors were fired ranged from 2 to 4 hr. The case temperature at ignition for these motors varied from 73 to 81°F. The Mark 11B/11C motors (P/N 331120-1 and 331121-1) were conditioned in the test cell in a temperature environment of 105 ± 2°F for a minimum of 2 hr prior to reducing the test cell pressure to simulated altitude conditions. The case temperature at ignition for these motors varied from 97 to 103°F.

After installation of three motor assemblies in the test cell, instrumentation connections were made, and a continuity check of all electrical systems was performed. Prefire, sea-level calibrations were completed, the test cell pressure was reduced to the desired simulated altitude condition, and the altitude calibrations were completed. The final operation prior to each firing was to adjust the firing circuit resistance and voltage to provide the desired firing current to the igniter squib (5 amp).

After the third firing in a test period, postfire calibrations were obtained, and the test cell pressure was returned to ambient pressure conditions. Each motor was inspected, photographed, and removed to the storage area. Postfiring inspections consisted of measuring the tube exit diameters, weighing the motor assembly, and photographically recording the postfire condition of the motor.

SECTION IV
RESULTS AND DISCUSSION

Twenty Atlantic Research Corporation (ARC) pitch motors (0.5-KS-30)(9 of P/N 331121-1 and 11 of P/N 330198-1), and twenty ARC spin motors (1-KS-30)(9 of P/N 330130-1 and 11 of P/N 331120-1), having ages ranging from 37 to 102 months, were tested at pressure altitudes ranging from 135,000 to 141,000 feet. The objectives of this program were to perform prescribed sinusoidal vibration tests, temperature cycling, electrical resistance tests and to determine motor ballistic performance at simulated altitude conditions to obtain data necessary to determine if the present service life of the motors can be extended. The results are discussed in the following section.

The nine spin motors (P/N 331120-1) and nine pitch motors (P/N 331121-1) were preconditioned in the test cell in a temperature environment of 105 ± 2°F for a minimum of 2 hours prior to firing. The eleven spin motors (P/N 330130-1) and eleven pitch motors (P/N 330198-1) were preconditioned in a temperature environment of 70 ± 2°F for a minimum of 24 hr prior to firing. The time interval from end of conditioning to firing was approximately 2 hr.

The motors were fired in a vertical position; therefore, the measured total impulse required a correction for the weight change of the motor during firing. This was accomplished by assuming that the motor weight loss was a linear function of time. The total impulse correction is therefore equal to one-half the motor weight change multiplied by the motor burn time. This correction ranged from 0.11 to 0.12 percent and from 0.16 to 0.19 percent of the average measured total impulse for the 0.5-KS-30 and the 1-KS-30 motors, respectively. The impulse data thus obtained were corrected to vacuum conditions by adding the product of the test cell pressure integral and the blast tube exit area. The vacuum correction ranged from 0.04 to 0.05 percent of the measured total impulse for the 0.5-KS-30 motors, and was approximately 0.04 percent for the 1-KS-30 motors.

4.1 PREFIRE VIBRATION, TEMPERATURE CYCLING, AND RESISTANCE TESTS

The motors were subjected to the prescribed prefire vibration and temperature cycling as outlined in Section III. A comparison of the pre- and postcycling X-rays of each motor revealed no physical degradation as a result of the vibration and temperature cycling.

Each motor was subjected to the prefire electrical resistance tests outlined in Section III. A tabulation of the resistance data is presented in Table II.

The motor Model Specifications (Refs. 4 through 7) require prefire igniter squib resistances of from 0.16 to 0.28 ohms for P/N's 330130-1 and 330198-1 and from 0.16 to 0.22 ohms for P/N's 331120-1 and 331121-1. All of the subject motors reported herein met the specification requirement. A summary of the squib resistance data for all of the Minuteman spin and pitch motors fired to date at AEDC (Refs. 8 through 17) is presented in Fig. 7.

The prefire igniter fuse resistance values ranged between 0.02 and 0.10 ohms (the Model Specification required that these values fall within a range of from 0.02 to 0.10 ohms). A summary of the igniter fuse resistance data for all of the Minuteman spin and pitch motors fired to date at the AEDC (Refs. 8 through 17) is presented in Fig. 8.

The Model Specification require that the igniter insulation resistance be a minimum of 10,000 ohms for P/N's 330130-1 and 330198-1 (Mark 11/11A motors); for P/N's 331120-1 and 331121-1 (Mark 11B/11C motors), the minimum requirement is 10 megohms. Two of the P/N 330130-1 spin motors, (S/N 0700156 and 0700043) and one of the P/N 331120-1 spin motors (S/N 0705732) failed to meet these specifications. For motor S/N 0705732, the resistance between igniter terminal D and case was 1.18Ω and between terminal E and case was 1.12Ω. For motor S/N 0700156, the resistance between shorted terminals DE and case was 400Ω. For motor S/N 0700043, the resistance between shorted pins DE and case was between 30 and 100Ω. All other motors met the igniter insulation resistance specifications.

4.2 ALTITUDE IGNITION CHARACTERISTICS

The motors were ignited (with 5 amp), using only one of the two squibs, at pressure altitudes ranging from 144,000 to 151,000 ft. (One motor, S/N 0600176, was inadvertently ignited at 95,000 ft during a test cell pressure transient prior to ignition.) The motors were subjected to the simulated altitude environment for approximately 1 hr prior to firing. The average case temperature at ignition for P/N's 331120-1 and 331121-1 was 100°F and for P/N's 330130-1 and 330198-1 was 76°F. The motors contained factory-installed nozzle throat closures designed to seal the motor chamber at essentially sea-level pressure conditions; however, the effectiveness of the seal could not be determined because chamber pressure was not measured.

During ignition of spin motors S/N 0700043 and 0700097, a failure occurred resulting in rupture of the case and ejection of the propellant grain, leaving the motor mounting flange attached to the thrust adapter. The failure was attributed to throat blockage by the nozzle plug which caused the case, already weakened by severe corrosion, to fail. A discussion of the structural integrity for these two motors is presented in Section 4.4. Performance data hereafter discussed pertains only to the remaining 38 motors, all of which performed satisfactorily.

Both thrust delay time (t_d) and ignition delay time (t_i) ranged from 1 to 5 msec for the motors reported herein. Thrust delay and ignition delay time obtained during testing of previous spin and pitch motors at the AEDC (Refs. 8 through 17) ranged from 2 to 8 msec.

4.3 ALTITUDE PERFORMANCE

A summary of the delivered vacuum total impulse for the 0.5-KS-30 and 1-KS-30 motors reported herein and for previous motors at the AEDC (Refs. 8 through 17) is presented in Figs. 9 and 10. Vacuum total impulse values are discussed below.

Typical variations of indicated thrust and test cell pressure with motor burn time for the motors reported herein are presented in Fig. 11. The data presented in Fig. 11 are based on values averaged over 0.050-sec time intervals (see Section 2.3). The actual instantaneous thrust, however, was determined for a typical spin and pitch motor firing (Fig. 12) by using a thrust compensation method (Ref. 19). The basic criterion for use of this method is that the thrust system behaves as a linear second-order system. For this method, the natural frequency and damping ratio of the thrust measuring system is used in an analog computer program to predict the true forcing function (motor thrust) from the thrust load cell output signal.

Full-duration burn time (t_{fb}) ranged from 0.494 to 0.540 sec for the 0.5-KS-30 motors and from 0.728 to 0.850 sec for the 1-KS-30 motors.

Thrust action time (t_{at}) ranged from 0.488 to 0.510 sec for the Mark 11/11A 0.5-KS-30 pitch motors and from 0.466 to 0.479 sec for the Mark 11B/11C 0.5-KS-30 pitch motors. These values fall within the limits set forth in the Model Specifications which are from 0.47 to 0.53 sec (Mark 11/11A) and from 0.43[1] to 0.51 sec (Mark 11B/11C, preconditioned at 105°F). Thrust action time ranged from 0.726 to 0.793 sec for the Mark 11/11A 1-KS-30 spin motors and falls within the range set forth in the Model Specification which is from 0.70 to 0.80 sec. The

[1]Lower limit for series 0606XXX motors is 0.39 sec.

thrust action time for one of the Mark 11B/11C spin motors, S/N 0705566, fell outside the range set forth in the specification,[2] which is from 0.64 to 0.74 sec. For this motor, the thrust action time was 0.752 sec. All the other Mark 11B/11C spin motors met the thrust action time requirements of the Model Specification.

Burn time (t_b) ranged from 0.417 to 0.473 sec and from 0.657 to 0.767 sec for the 0.5-KS-30 and 1-KS-30 motors, respectively.

Vacuum total impulse values ranged from 15.425 to 15.698 lbf-sec and from 15.640 to 15.758 lbf-sec for the 0.5-KS-30 motors, P/N's 330198-1 and 331121-1, respectively. These values are within the limits set forth in the Model Specifications (Refs. 4 and 6), which are 14.60 to 16.72 lbf-sec and 15.05 to 16.73 lbf-sec for P/N's 330198-1 and 331121-1, respectively. Vacuum total impulse values ranged from 28.764 to 29.361 lbf-sec and from 28.618 to 29.438 lbf-sec for the 1-KS-30 motors, P/N's 330130-1 and 331120-1, respectively. These values meet the specification limits (Refs. 5 and 7) which are 28.60 to 30.90 lbf-sec and from 28.46 to 30.74 lbf-sec for P/N's 330130-1 and 331120-1,[3] respectively. One of the series 0706XXX spin motors reported herein failed to meet this specification. The vacuum total impulse for motor S/N 0706072 was 28.618 lbf-sec which fell below the specification minimum of 28.90 lbf-sec.

The vacuum specific impulse based on the manufacturer's stated propellant weight averaged 226.9 lbf-sec/lbm for the 0.5-KS-30 motors and 224.4 lbf-sec/lbm for the 1-KS-30 motors. A summary of motor ballistic performance is presented in Table III.

4.4 STRUCTURAL INTEGRITY

Prefire examination of spin motors (S/N 0700043 and 0700097) revealed severe corrosion of the blast tube interior (Fig. 13) and lesser corrosion of the mounting flange/case interface. Visual inspection also revealed that the silicone rubber nozzle throat plug was not properly positioned in these two motors. Radiographic inspection of the motors disclosed similarly severe corrosion of the case interior and revealed that the throat plug was inside the motor case, resting at the annular entrance to the cylindrically perforated propellant grain (Fig. 14). Prefire examination of the remaining 38 motors revealed that all nozzle plugs were properly installed and that no corrosion or deterioration was evidenced. A postfire photograph of the remains of motors S/N 0700043 and 0700097 is presented in Fig. 15.

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[2]The action time requirement for Mark 11B/11C series 0706XXX spin motors is 0.65 to 0.75 sec.

[3]For series 0706XXX motors, the specification requirement for vacuum total impulse is from 28.90 to 30.12 lbf-sec.

Postfire examination of the remains of these motors (Fig. 16a) confirmed the severe interior case corrosion disclosed by the prefire radiographs. The case thickness varied from 0.010 to 0.025 in. Normal case thickness is 0.040 in. The throat plug was "wedged" in the convergent nozzle entrance (Fig. 16a). The propellant grain for both motors was observed to have a porous, mottled surface, which did not appear to have been ignited (Fig. 16b), because rust contamination from the case was observed on the periphery.

Postfire examination of the remaining 38 motors indicated the structural integrity to be satisfactory.

SECTION V
SUMMARY OF RESULTS

Twenty ARC pitch motors (0.5-KS-30)(9 of P/N 331121-1 and 11 of P/N 330198-1) and twenty ARC spin motors (1-KS-30)(9 of P/N 331120-1 and 11 of P/N 330130-1), having ages ranging from 37 to 102 months, were subjected to sinusoidal vibration tests (P/N's 331121-1 and 331120-1 only), temperature cycling, and electrical resistance measurements and then tested at ignition altitudes ranging from 144,000 to 151,000 ft to investigate the possibility of extending the service life of the motors. The test results are summarized as follows:

1. Spin motors S/N 0700043 and 0700097 (P/N 330130-1) failed immediately after application of ignition signal, resulting in case rupture and ejection of the propellant grain. The failure was attributable to throat blockage by the nozzle plug which prefire examination revealed to be inside the motor rather that properly positioned at the nozzle throat.

2. Prefire examination (visual and radiographic) of spin motors S/N 0700043 and 0700097 revealed severe corrosion of the blast tube and case interior, lesser corrosion of the mounting flange/case interface, and disclosed the silicone rubber nozzle throat plug to be contained entirely within the motor.

3. Nine pitch motors (P/N 331121-1) and nine spin motors (P/N 331120-1) were subjected to a 3.5-g rms, (limited to 0.4-in. double amplitude) sinusoidal vibration in the frequency range from 10 to 2000 Hz, input at the motor mounting fixture, at a rate of one-half octave each minute in the three perpendicular axes. All motors were exposed to a temperature cycling environment as follows: from ambient to +125°F in 4 hr; remain at

+125°F for a 72-hr soak; from +125 to -35°F in 4 hr; remain at -35°F for a 72-hr soak; from -35 to +70°F in 2 min; remain at +70°F for an 8-hr soak. The X-ray inspections performed before and after the vibration and temperature cycling revealed no degradation of the motor structural integrity.

4. The igniter squib prefire resistance for all the motors met the Model Specification limits of from 0.16 to 0.28 ohms for P/N's 330198-1 and 330130-1 and from 0.16 to 0.22 ohms for P/N's 331121-1 and 331120-1.

5. The igniter fuse prefire resistance for all motors met the Model Specification limits of from 0.02 to 0.10 ohms.

6. Three of the spin motors failed to meet the igniter insulation resistance requirements of the Model Specifications. For motor S/N 0705732, the resistance between terminal D and case was 1.18 ohms and between terminal E and case was 1.12 ohms. The Specifications require a minimum resistance of 10 megohms for P/N 331120-1. For motor S/N 0700156, the resistance between shorted terminals DE and case was 400 ohms. For motor S/N 0700043, the resistance between shorted pins DE and case was between 30 and 100 ohms. For these two motor types (P/N 330130-1), the Specifications require a minimum resistance of 10,000 ohms. All other motors met the ignition insulation resistance requirements.

7. The interval from the time of application of ignition current to the time that thrust reached 10 percent of maximum during ignition ranged from 1 to 5 msec.

8. The interval from the time of increase in thrust during ignition to the time that thrust had decreased to zero during tailoff ranged from 0.728 to 0.850 sec for the 1-KS-30 motors and from 0.494 to 0.540 sec for the 0.5-KS-30 motors.

9. Thrust action time, defined as the time interval between 10 percent of maximum thrust (i.e., highest thrust developed during a firing, excluding ignition peak) during ignition and 10 percent of maximum thrust during tailoff ranged from 0.488 to 0.510 sec for the Mark 11/11A 0.5-KS-30 pitch motors which falls within the 0.47- to 0.53-sec range set forth in the Model Specifications. Thrust action time for the Mark 11B/11C

0.5-KS-30 pitch motors ranged from 0.466 to 0.479 sec which falls within the specification range of from 0.43 to 0.51 sec (motors preconditioned at 105°F). Thrust action time for the Mark 11/11A 1-KS-30 spin motors ranged from 0.726 to 0.793 sec which falls within the specification limits of from 0.70 to 0.80 sec. The thrust action time for Mark 11B/11C 1-KS-30 spin motor S/N 0705566 was 0.752 sec which fell outside the specification limits of from 0.64 to 0.74 sec. The remaining Mark 11B/11C spin motors met the specification requirements for thrust action time.

10. Vacuum total impulse values ranged from 15.425 to 15.698 lbf-sec and from 15.640 to 15.758 lbf-sec for the 0.5-KS-30 motors (P/N's 330198-1 and 331121-1), respectively. Vacuum total impulse values ranged from 28.764 to 29.361 lbf-sec and from 28.618 to 29.438 lbf-sec for the 1-KS-30 motors (P/N's 330130-1 and 331120-1), respectively. The vacuum total impulse value of one series 0706XXX Mark 11B/11C spin motor (S/N 0706072) was 28.618 lbf-sec , which fell below the specification minimum of 28.90 lbf-sec. All remaining values are within the ranges prescribed by Model Specifications.

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5. Model Specification S-133-1005-0-1-6, for Rocket Motor Assembly Spin A/A44A-8. June 28, 1963.

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7. Model Specification S-133-1005-33, for Rocket Motor YSR61-AR-1 (Spin), December 16, 1965.

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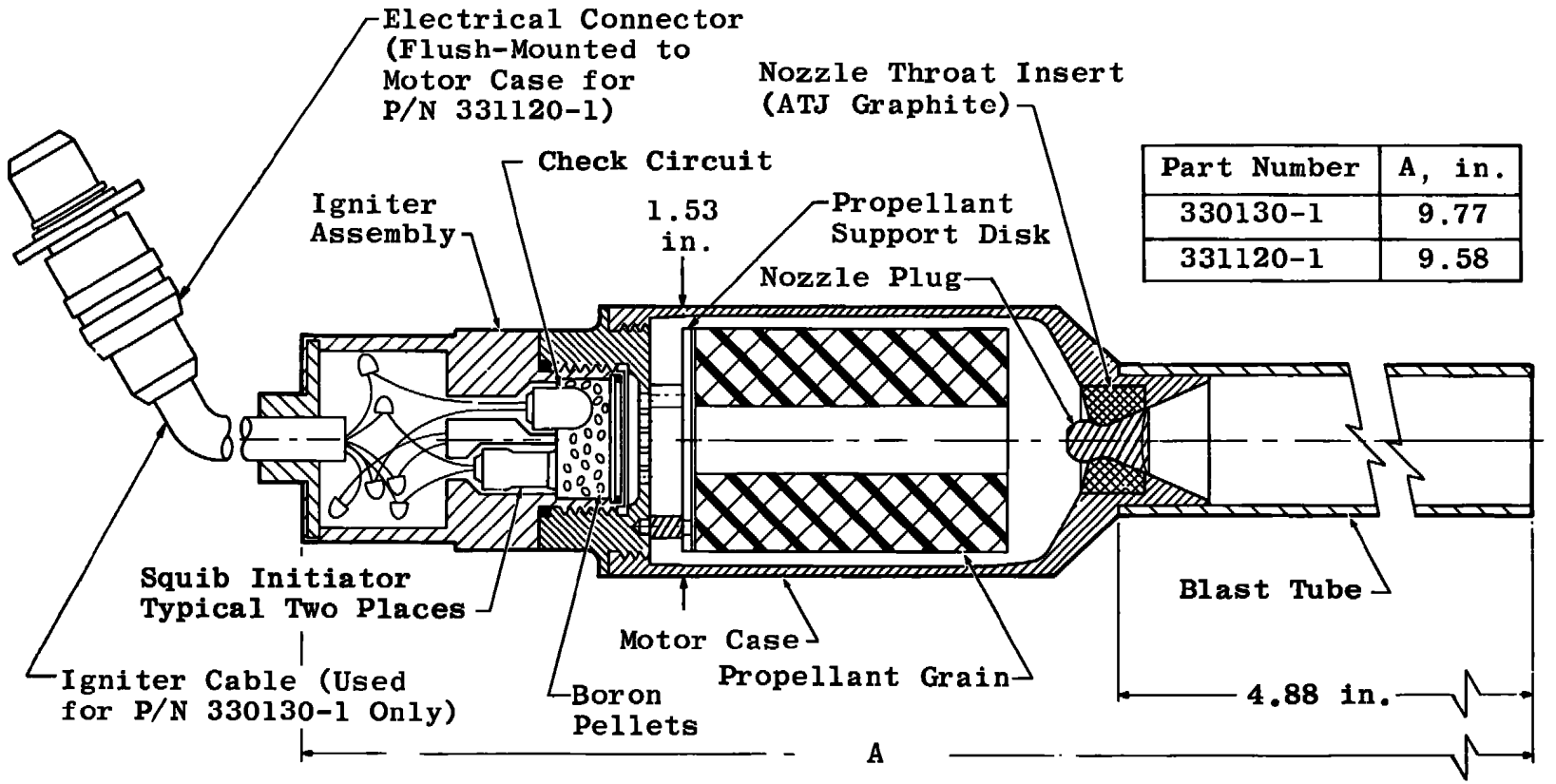
APPENDIXES

I. ILLUSTRATIONS

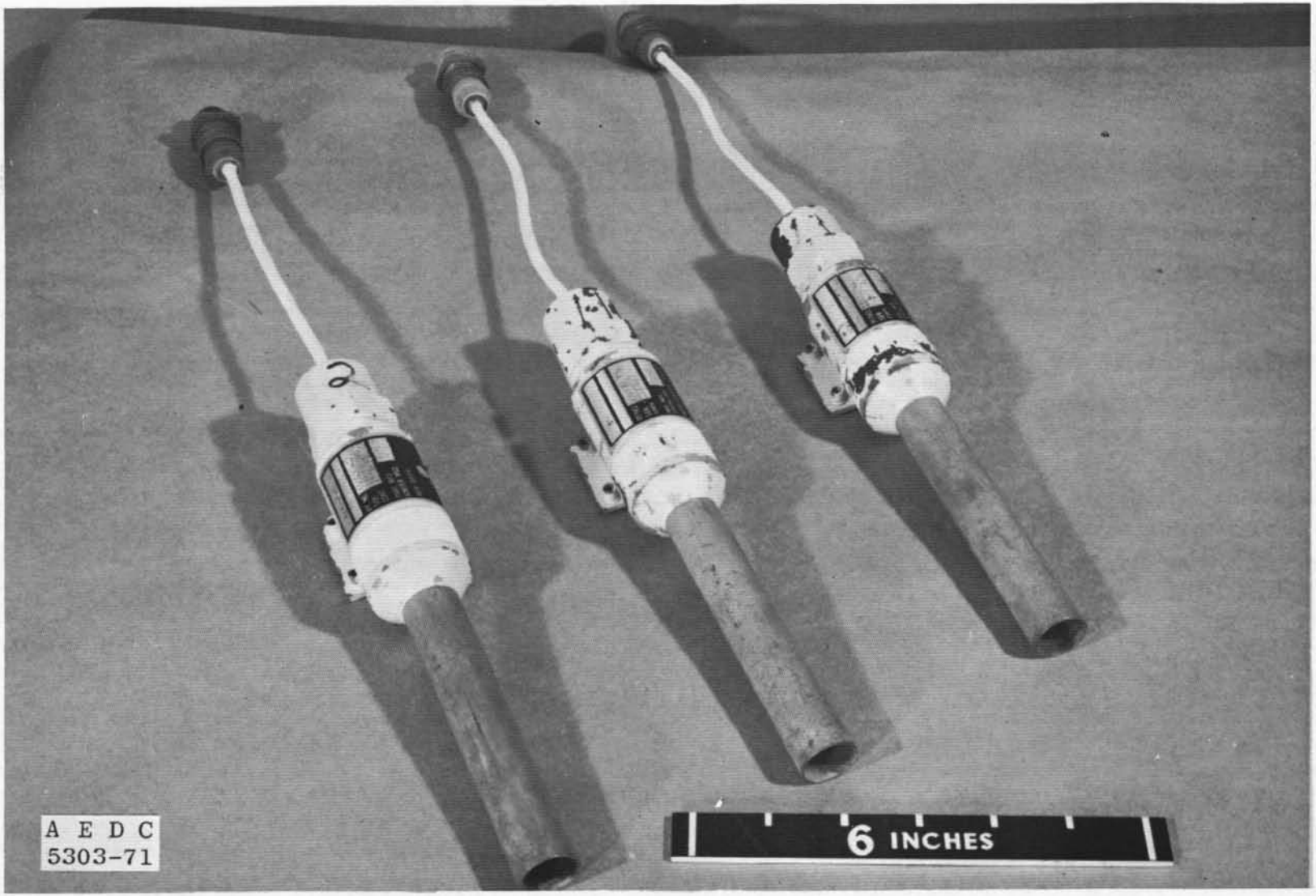
II. TABLES



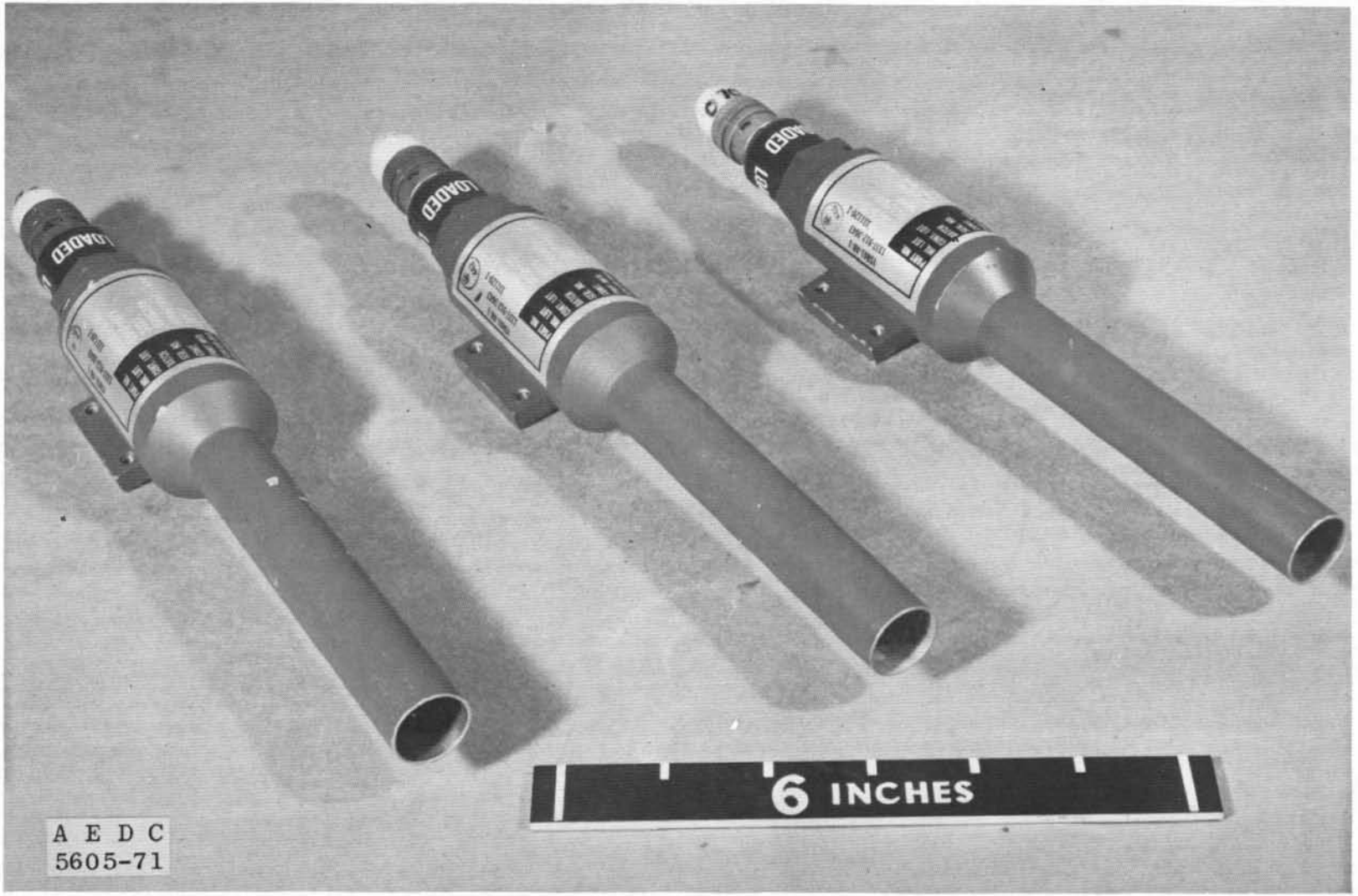
Part Number	A, in.
330130-1	9.77
331120-1	9.58

a. Schematic

Fig. 1 ARC Mark 11 Reentry Vehicle Spin Motor (1-KS-30)

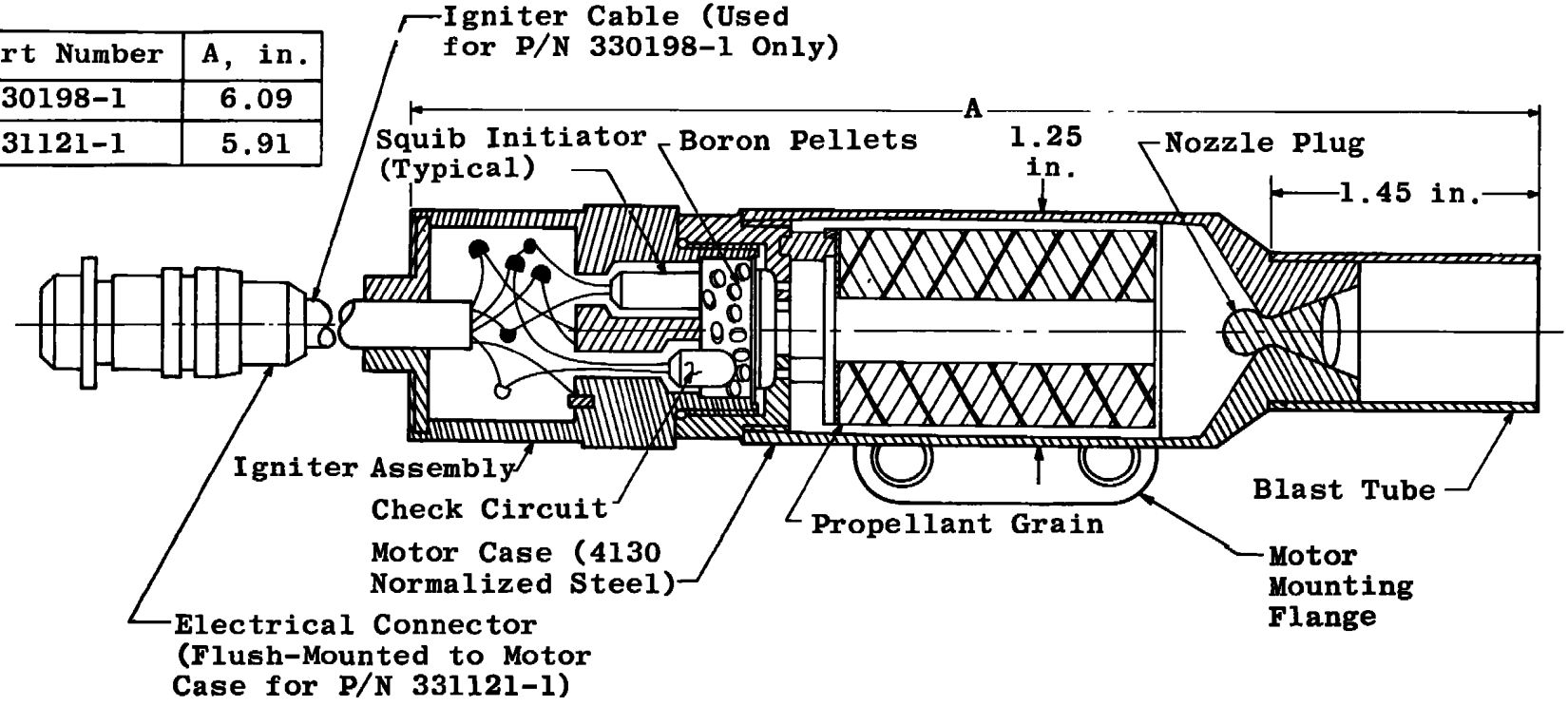


b. Photograph (P/N 330130-1)
Fig. 1 Continued



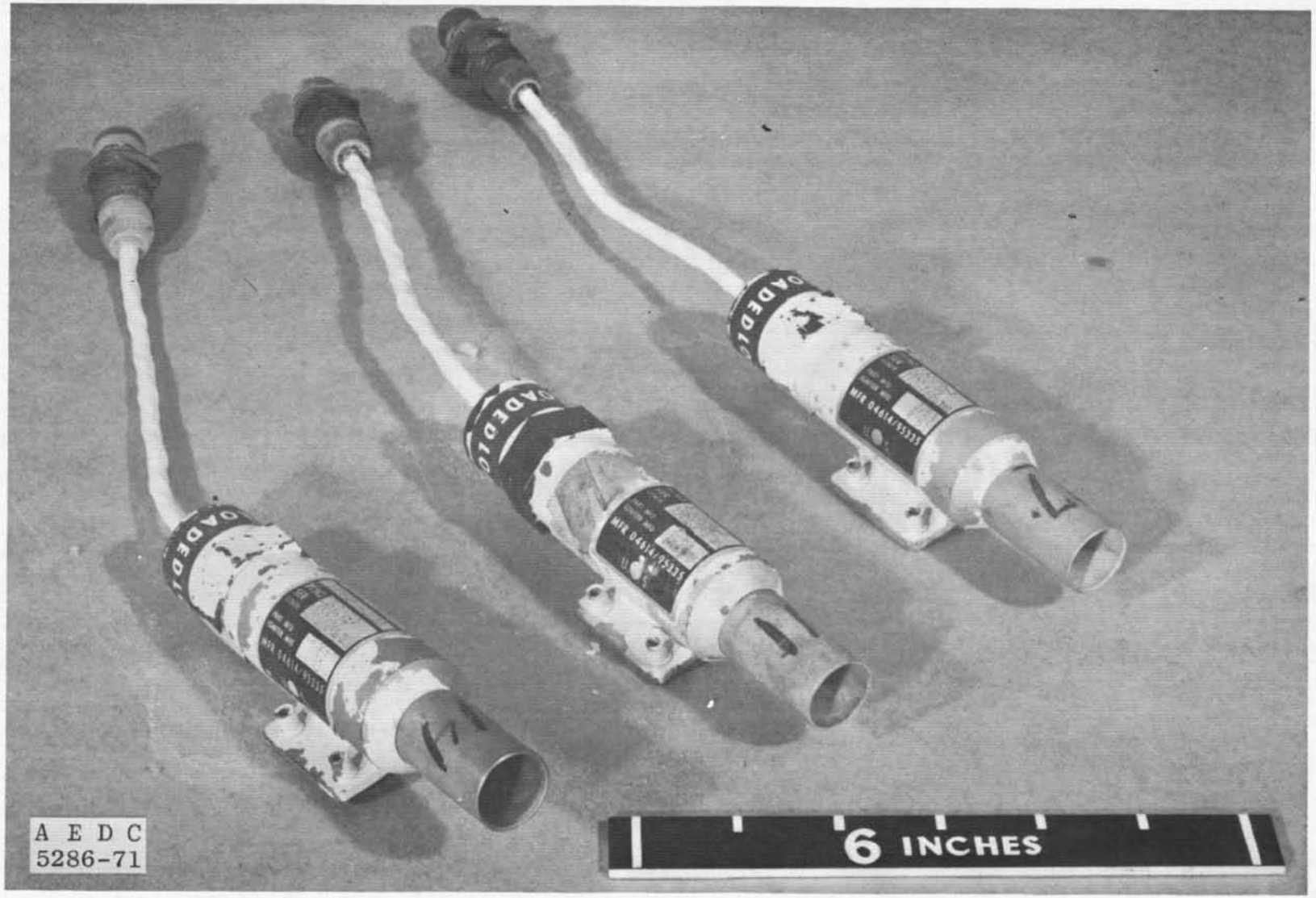
c. Photograph (P/N 331120-1)
Fig. 1 Concluded

Part Number	A, in.
330198-1	6.09
331121-1	5.91



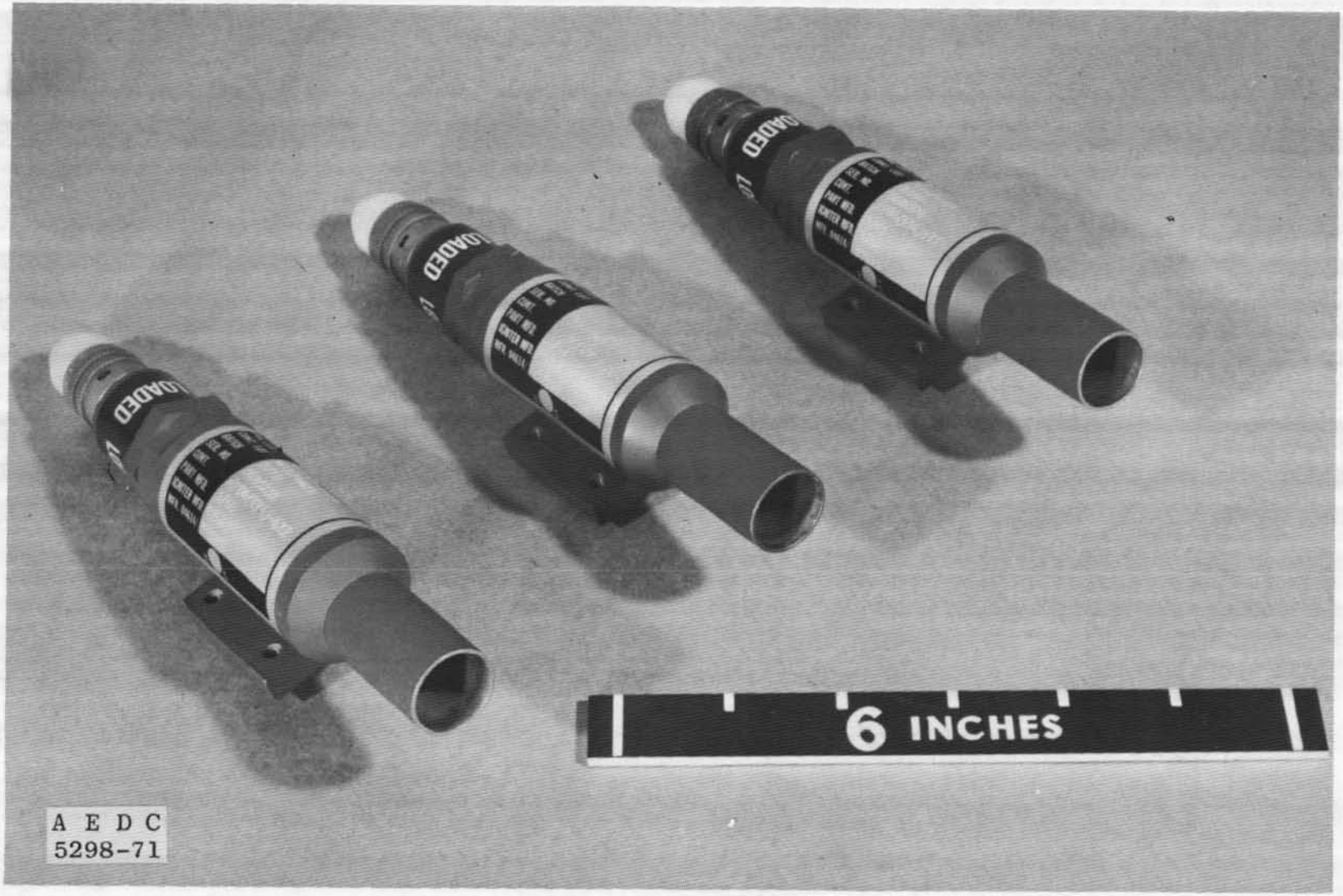
a. Schematic

Fig. 2 Mark 11 Reentry Vehicle Pitch Motor (0.5-KS-30)

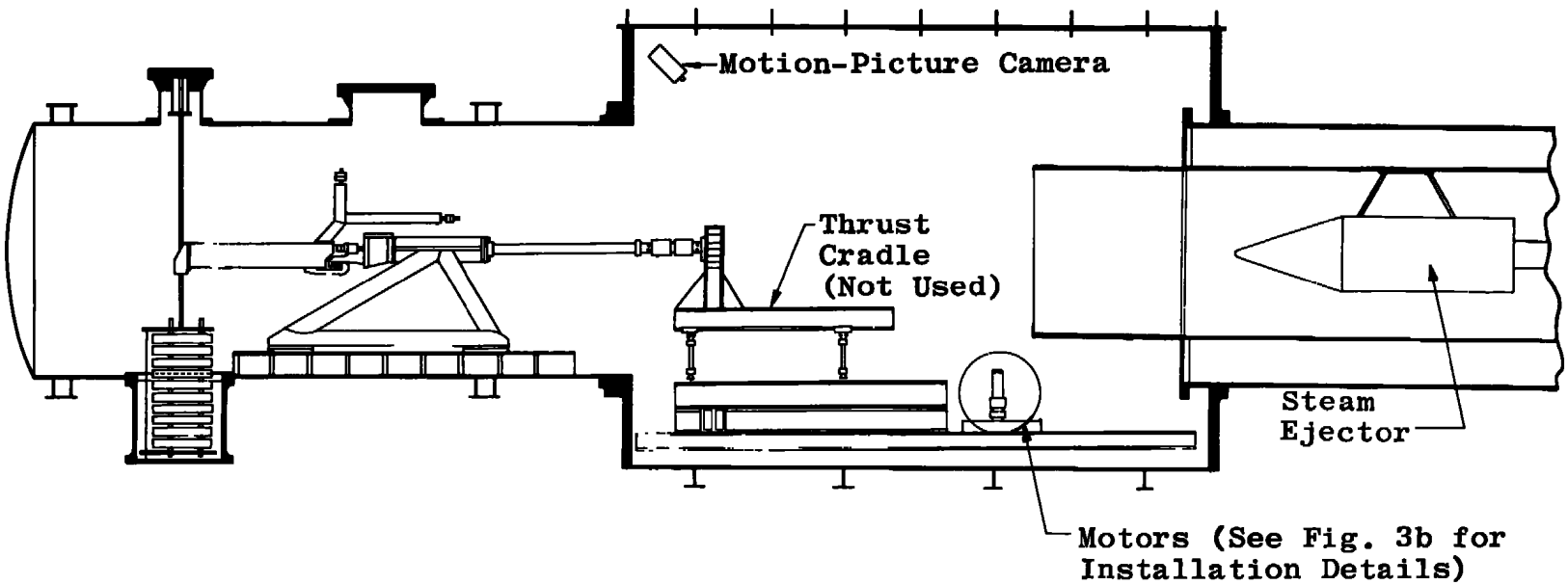


b. Photograph (P/N 330198-1)

Fig. 2 Continued

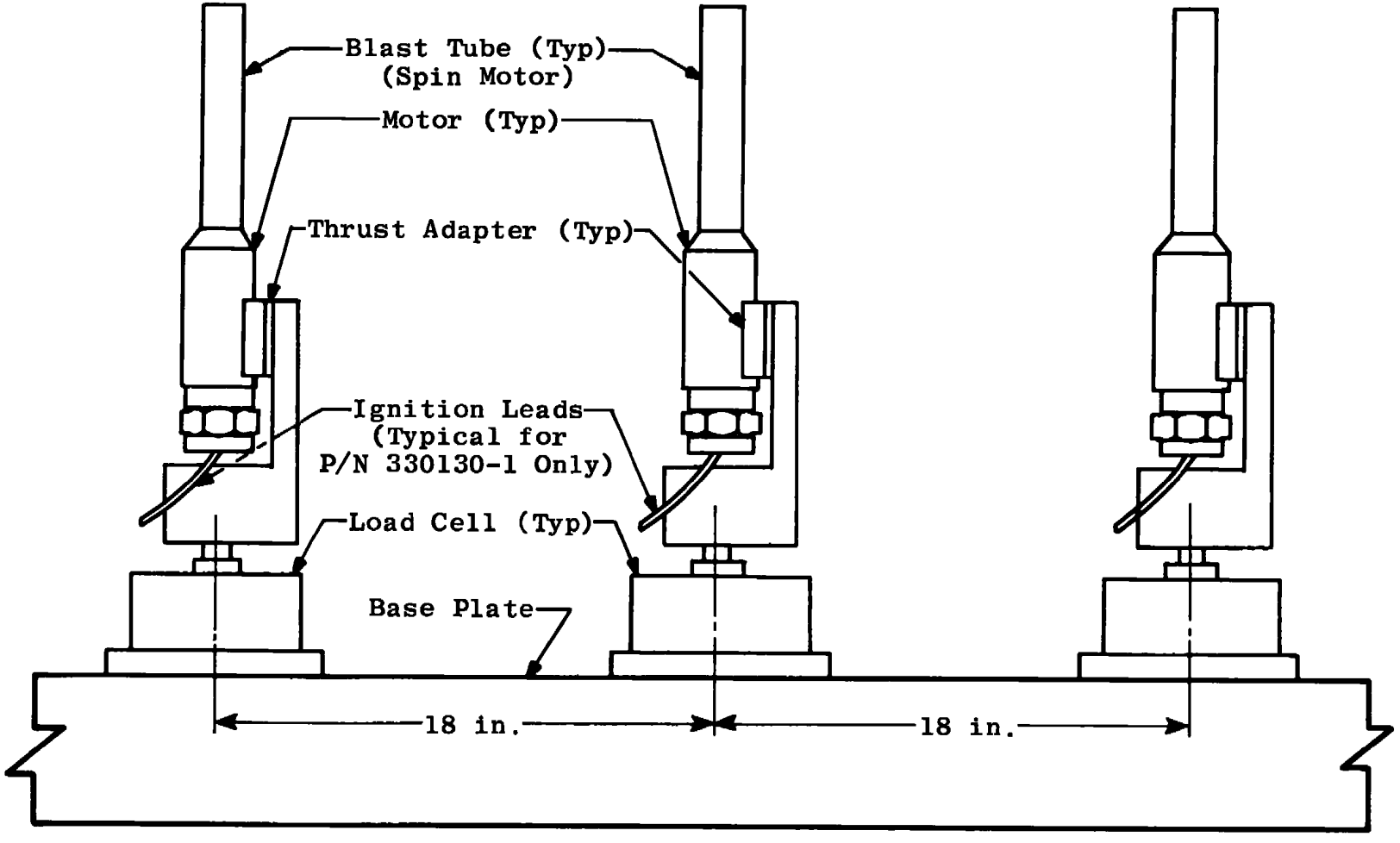


c. Photograph (P/N 331121-1)
Fig. 2 Concluded

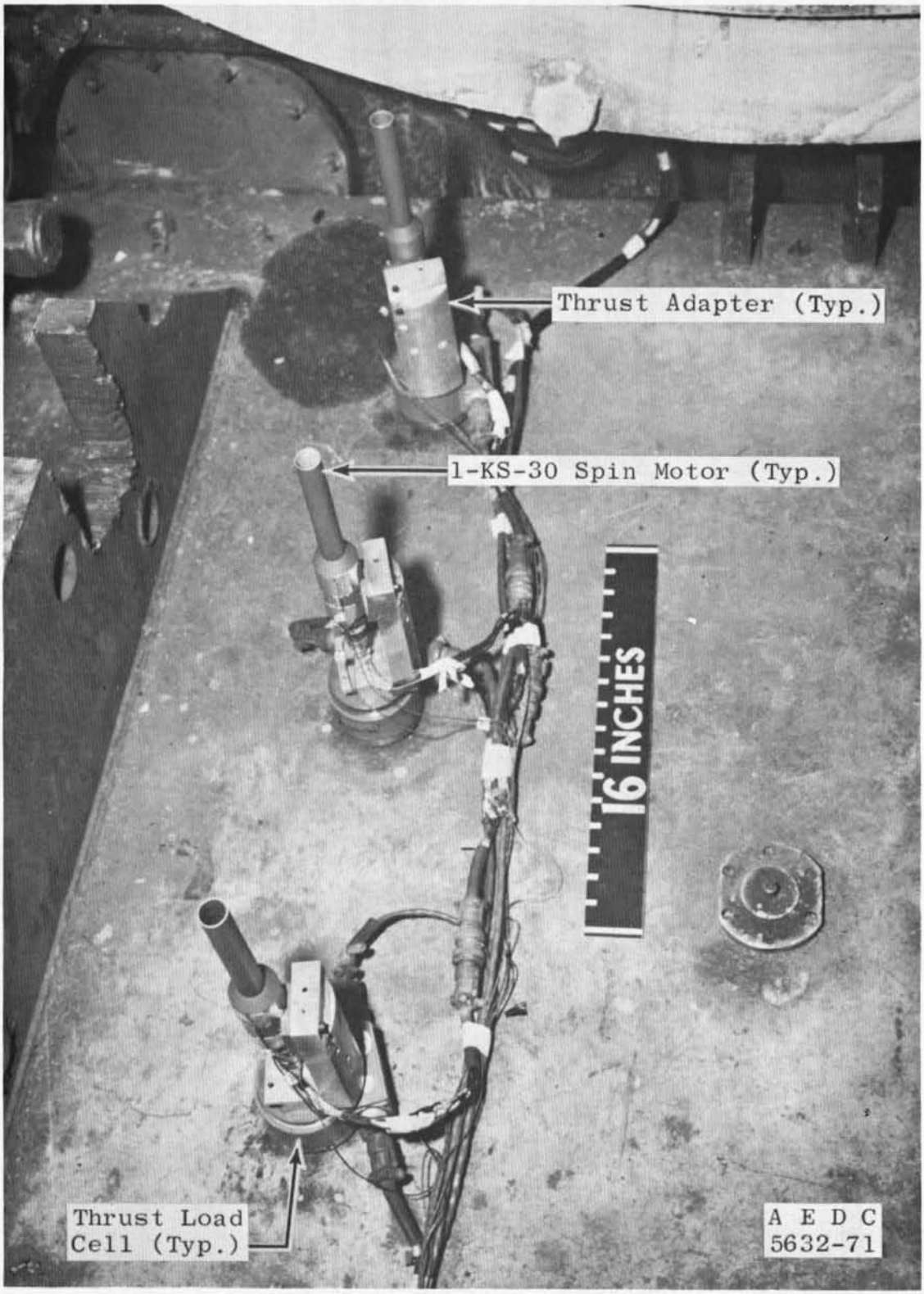


a. Overall Schematic

Fig. 3 Typical Installation of Motors in Propulsion Engine Test Cell (T-3)



b. Detail
Fig. 3 Continued



c. Photograph
Fig. 3 Concluded

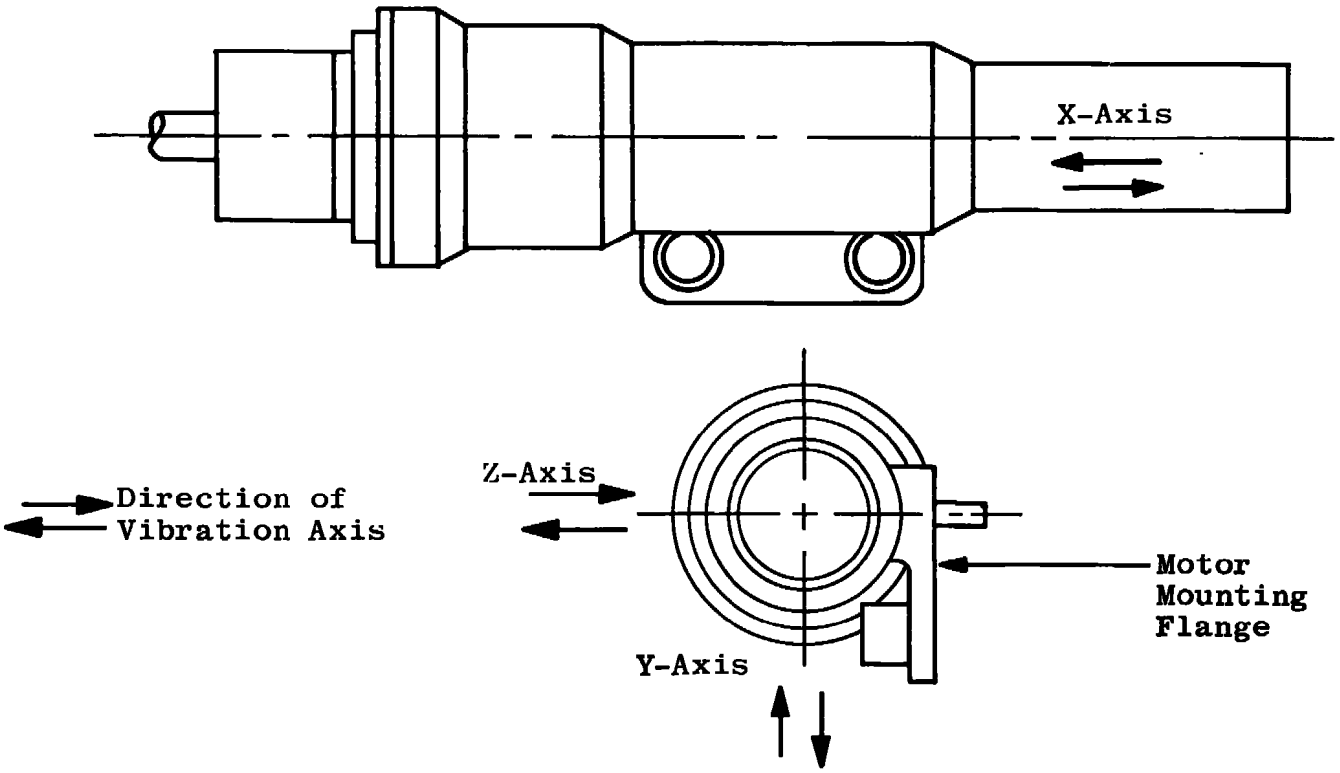
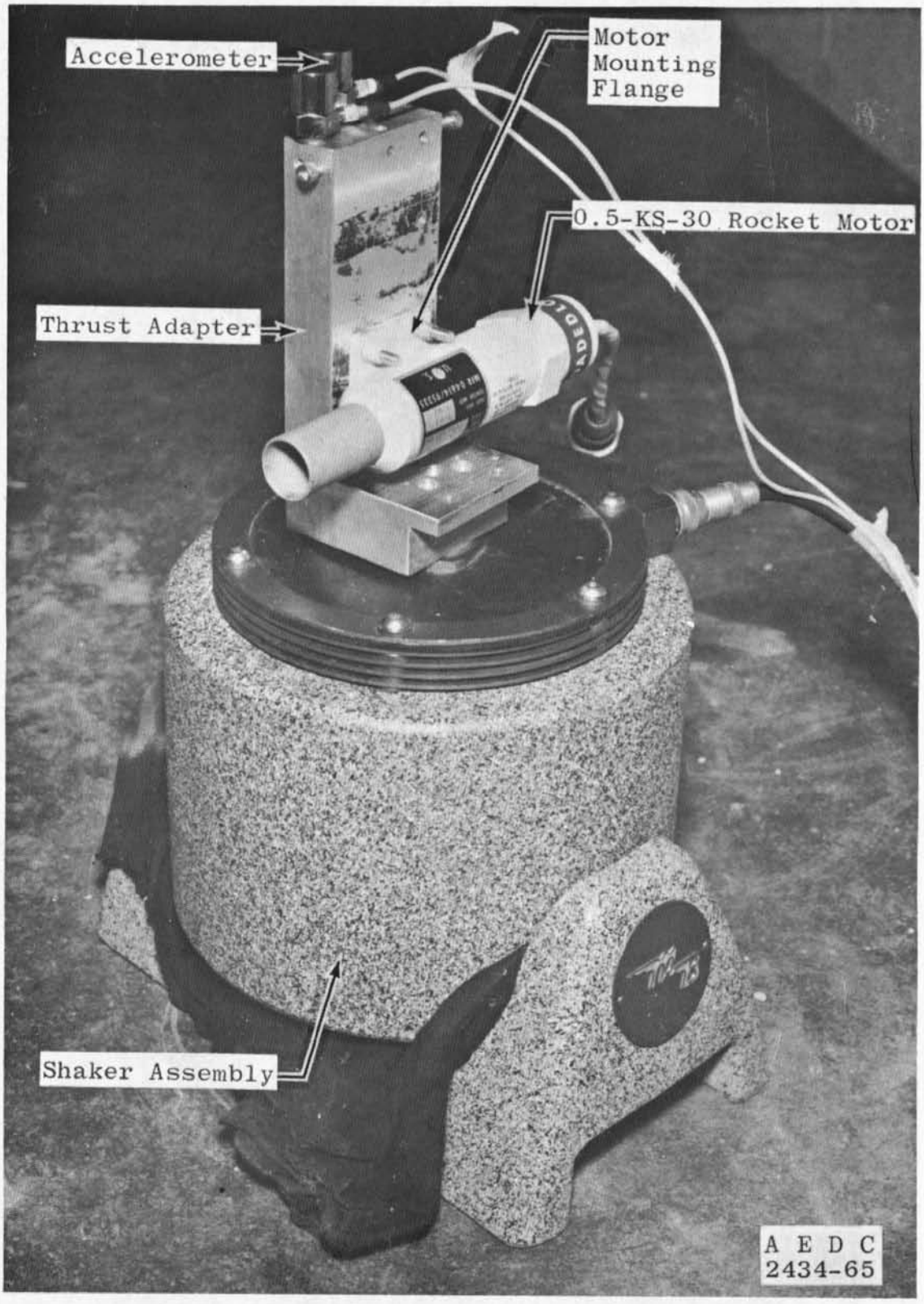
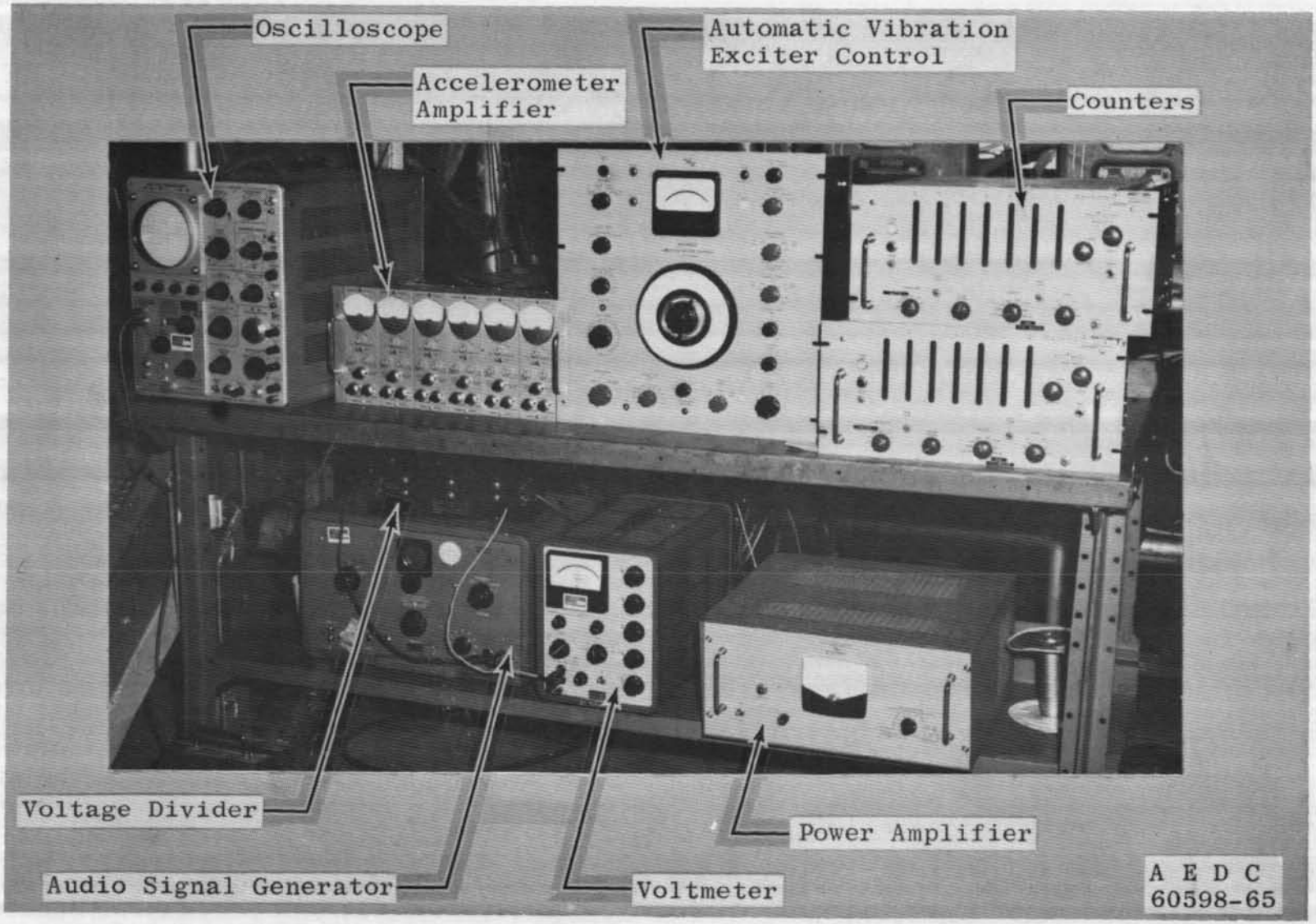


Fig. 4 Schematic Showing the Three Mutually Perpendicular Motor Axes for the Sinusoidal Vibration Input



a. Shaker Assembly (Motor Mounted for Y-Axis Vibration)

Fig. 5 Photographs Showing Vibrational Equipment and Related Controls



b. Shaker Assembly Controls
Fig. 5 Concluded

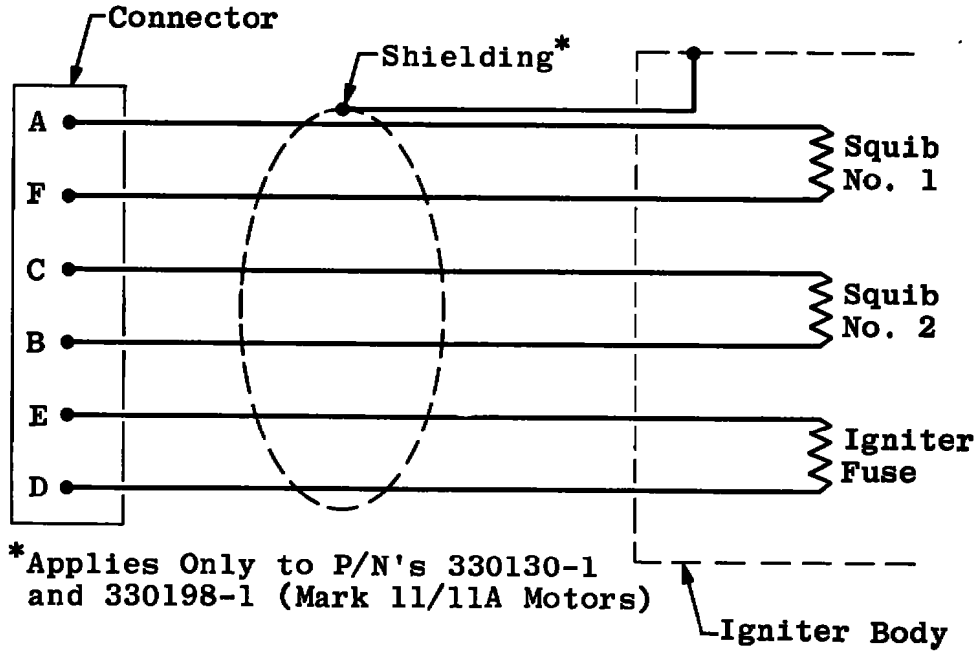
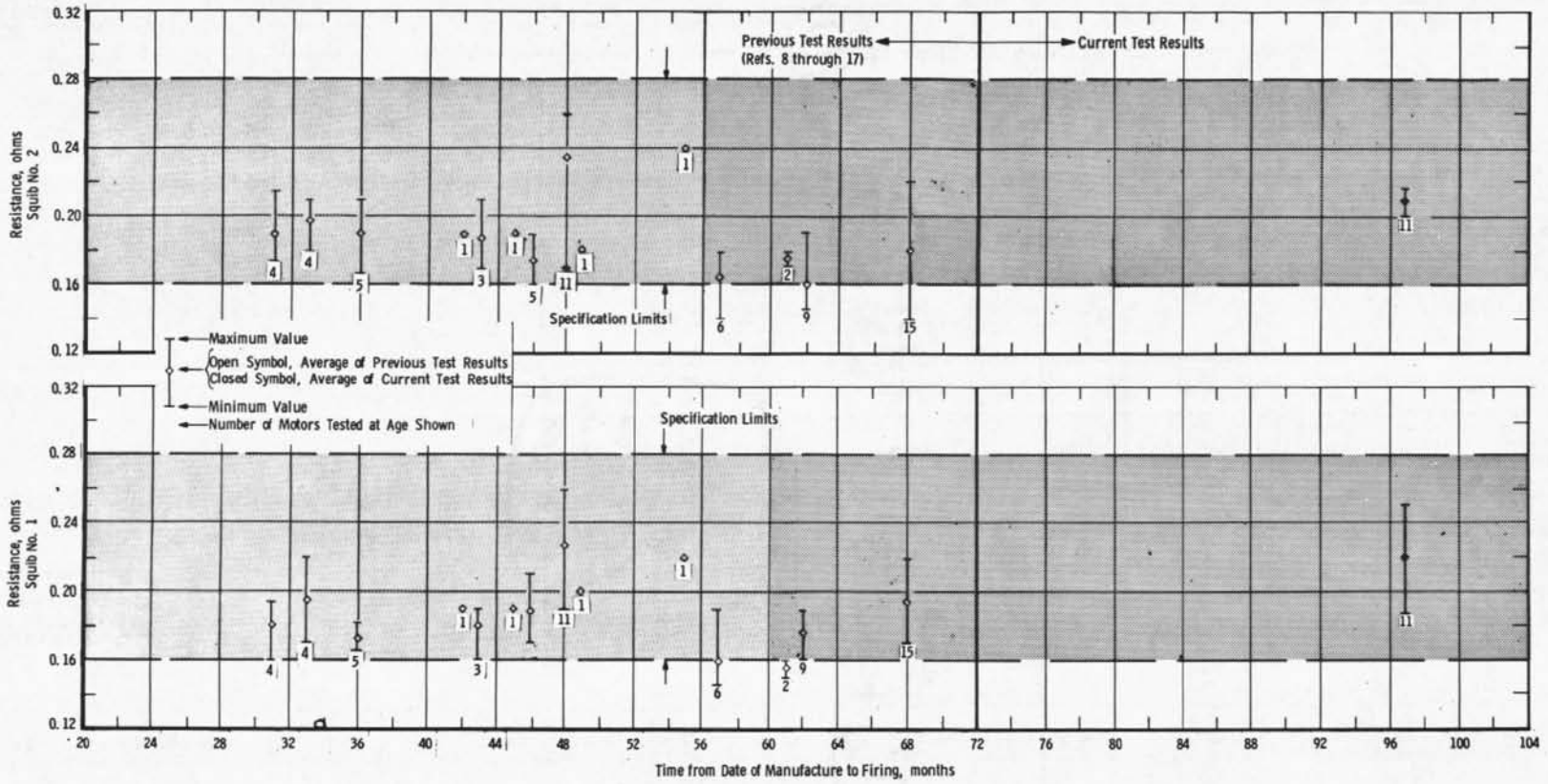
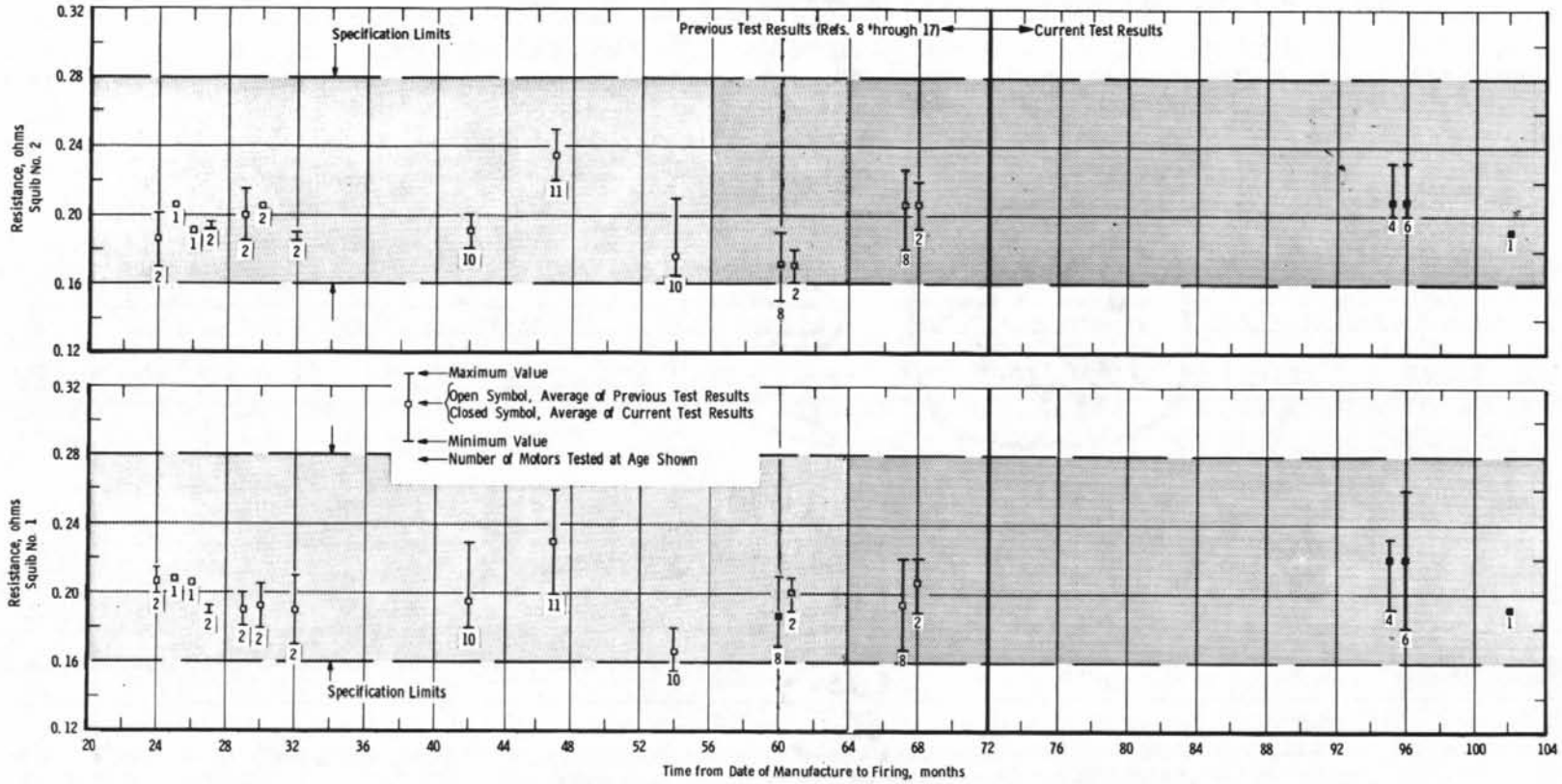


Fig. 6 Electrical Schematic of Igniter Body and Connector

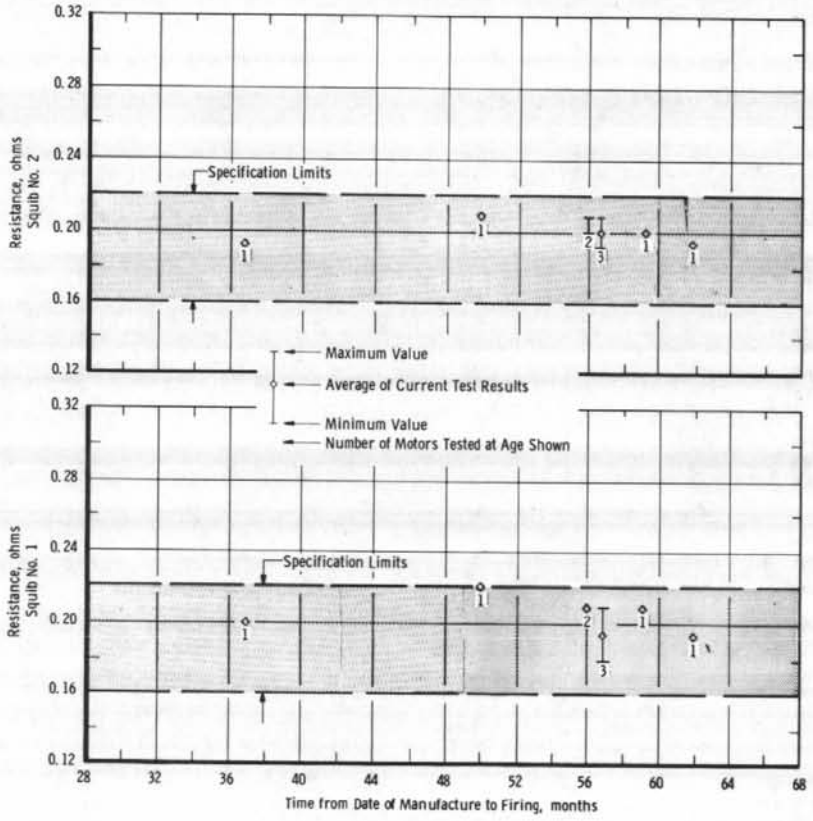


a. Mark 11/11A 1-KS-30 Motors (P/N 330130-1)

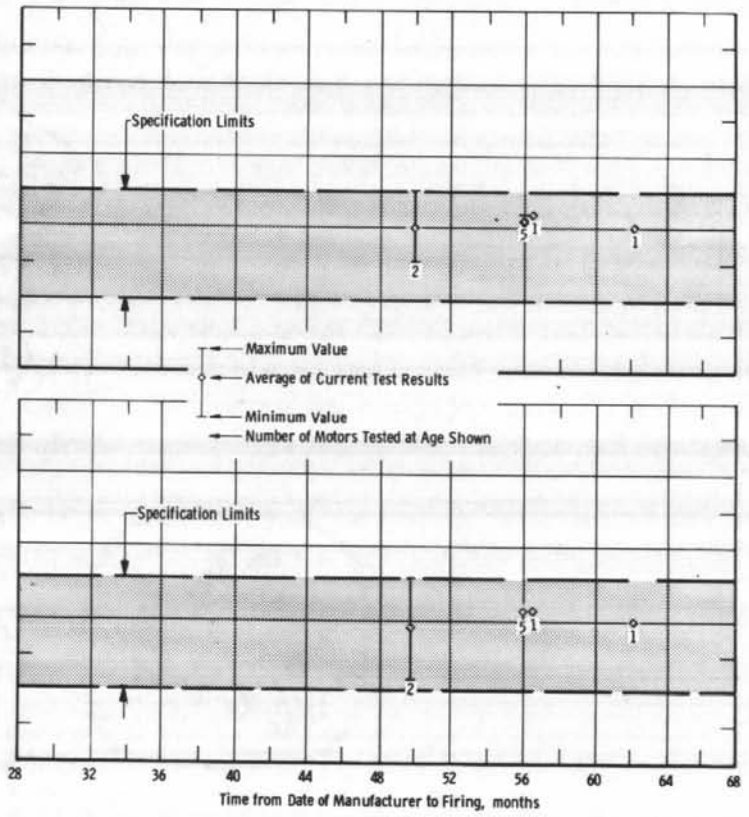
Fig. 7 Variation of Prefire Squib Resistance with Age for the Spin and Pitch Motors Fired to Date



b. Mark 11/11A 0.5-KS-30 Motor (P/N 330198-1)
Fig. 7 Continued

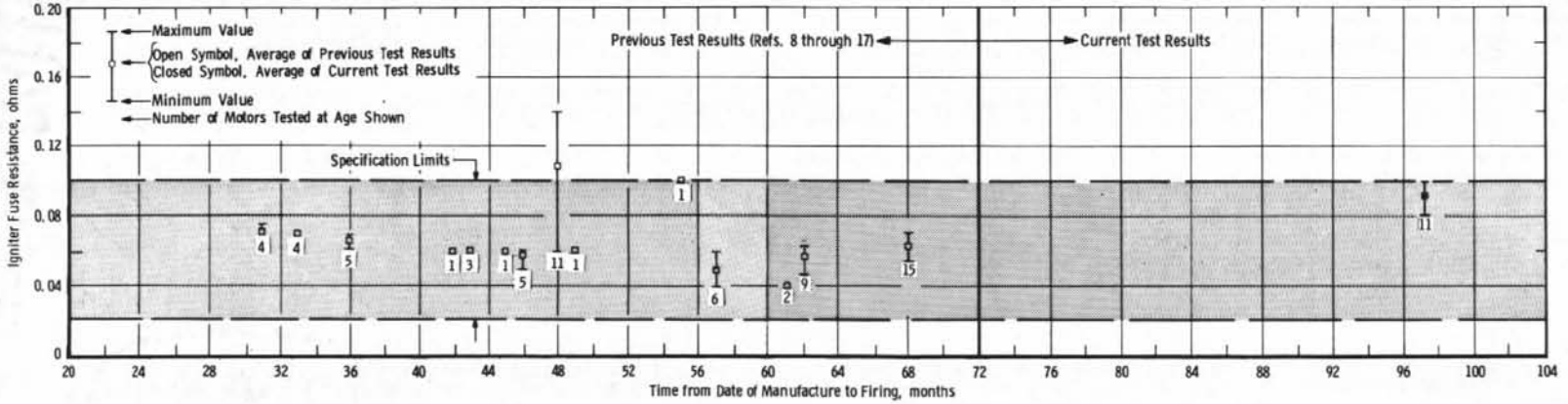


c. Mark 11B/11C 1-KS-30 Motors (P/N 331120-1)

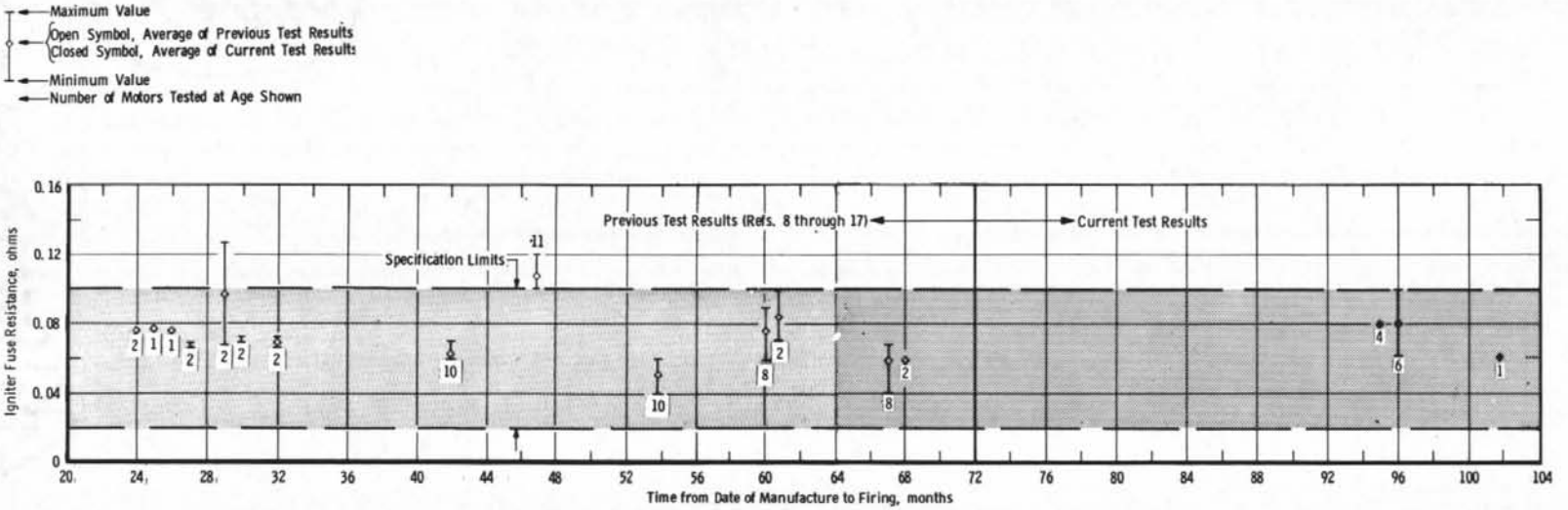


d. Mark 11B/11C 0.5-KS-30 Motors (P/N 331121-1)

Fig. 7 Concluded

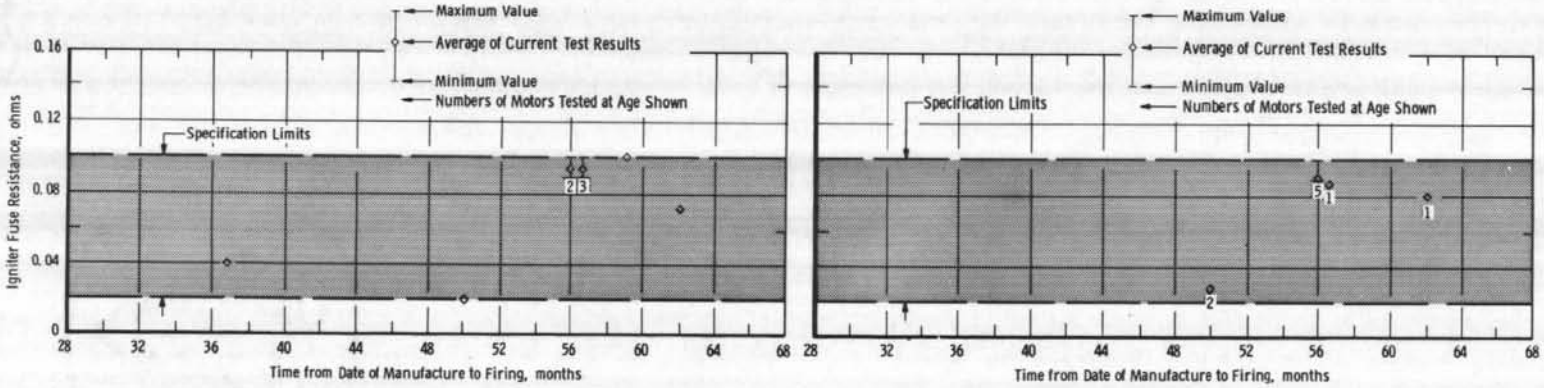


a. Mark 11/11A 1-KS-30 Motors (P/N 330130-1)



b. Mark 11/11A 0.5-KS-30 Motors (P/N 330198-1)

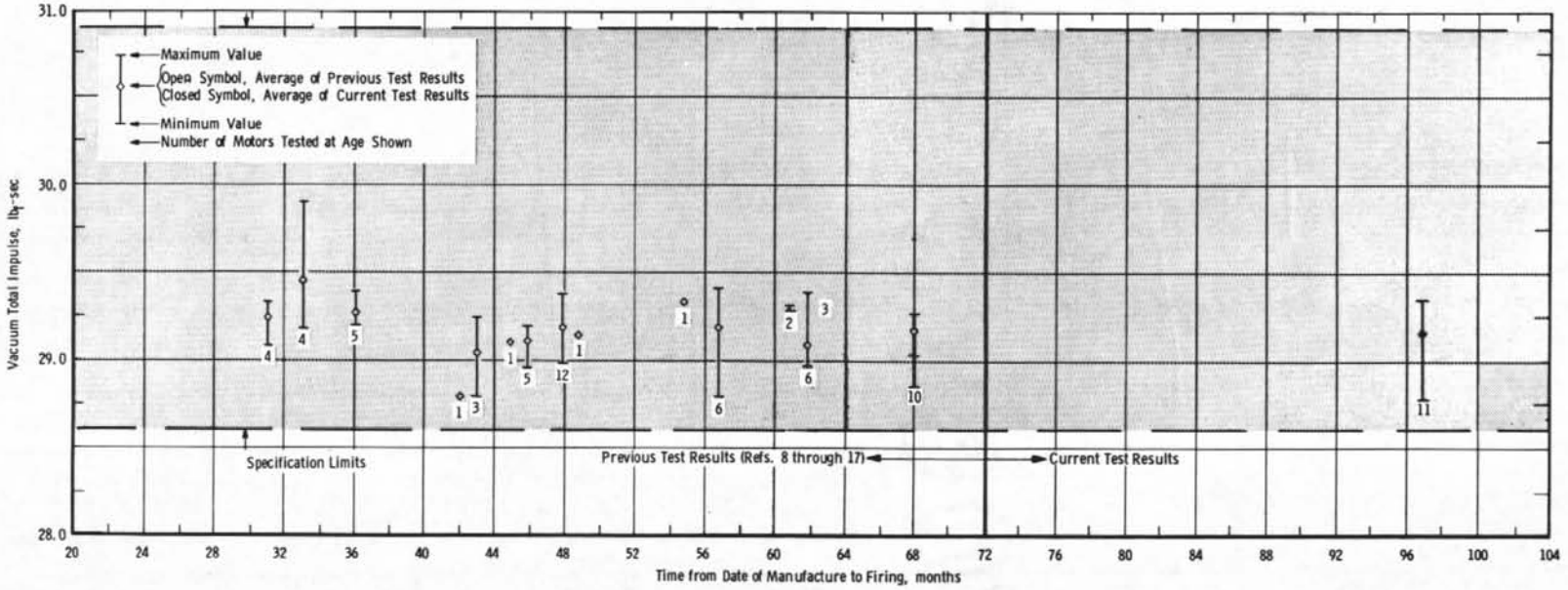
Fig. 8 Variation of Prefire Igniter Fuse Resistance with Age for the Spin and Pitch Motors Fired to Date



c. Mark 11B/11C 1-KS-30 Motors (P/N 331120-1)

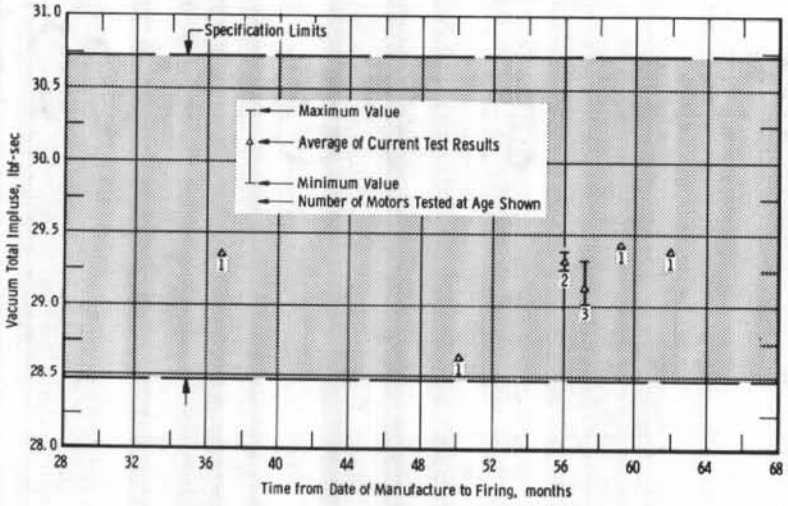
d. Mark 11B/11C 0.5-KS-30 Motors (P/N 331121-1)

Fig. 8 Concluded

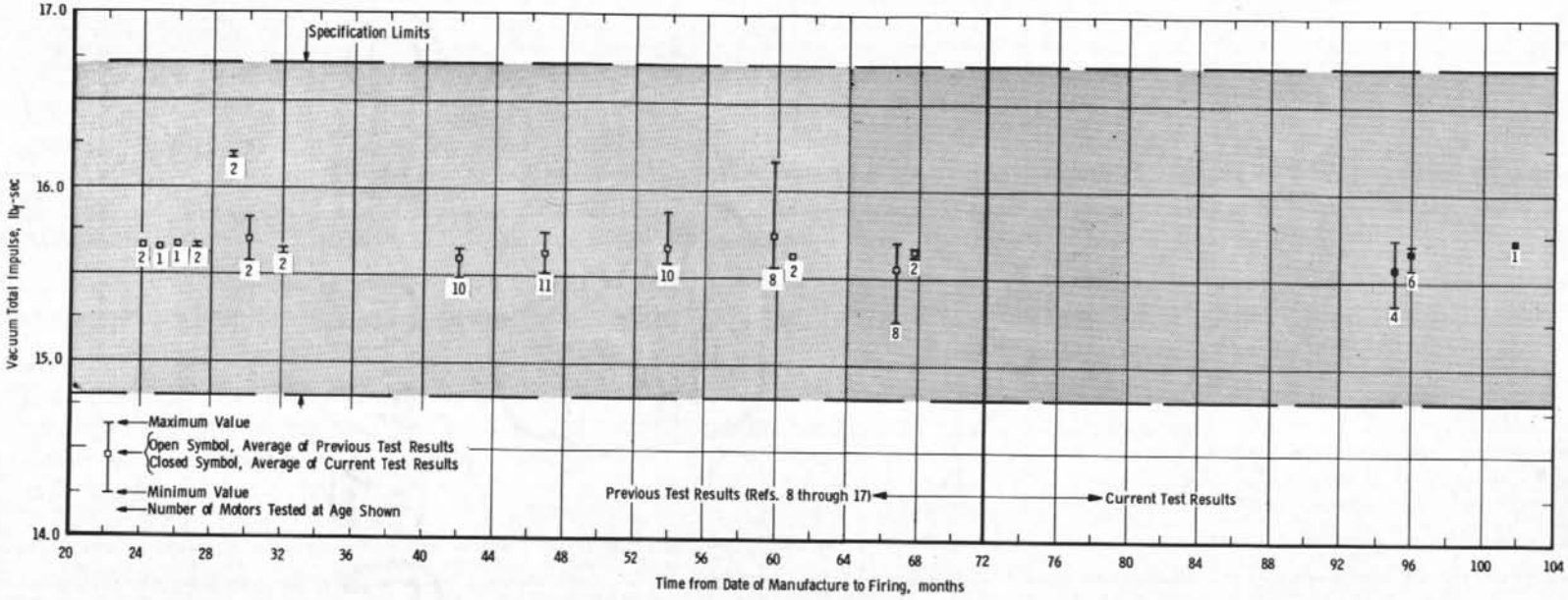


a. Mark 11/11A (P/N 330130-1)

Fig. 9 Variation of Delivered Vacuum Total Impulse with Age for the 1-KS-30 Spin Motors Fired to Date

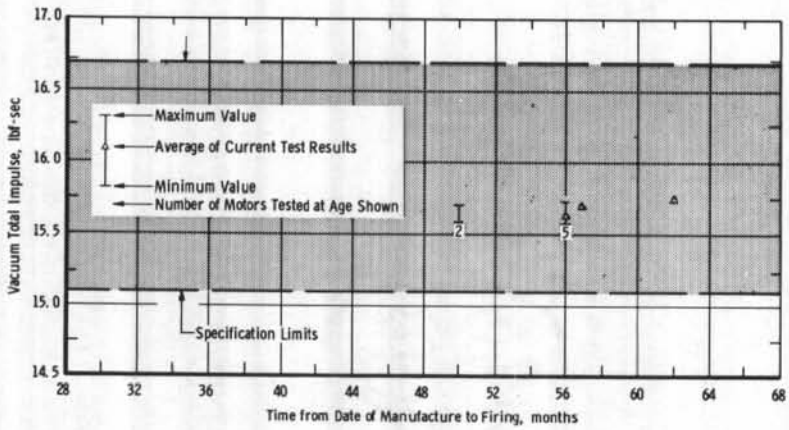


b. Mark 11B/11C (P/N 331120-1)
Fig. 9 Concluded

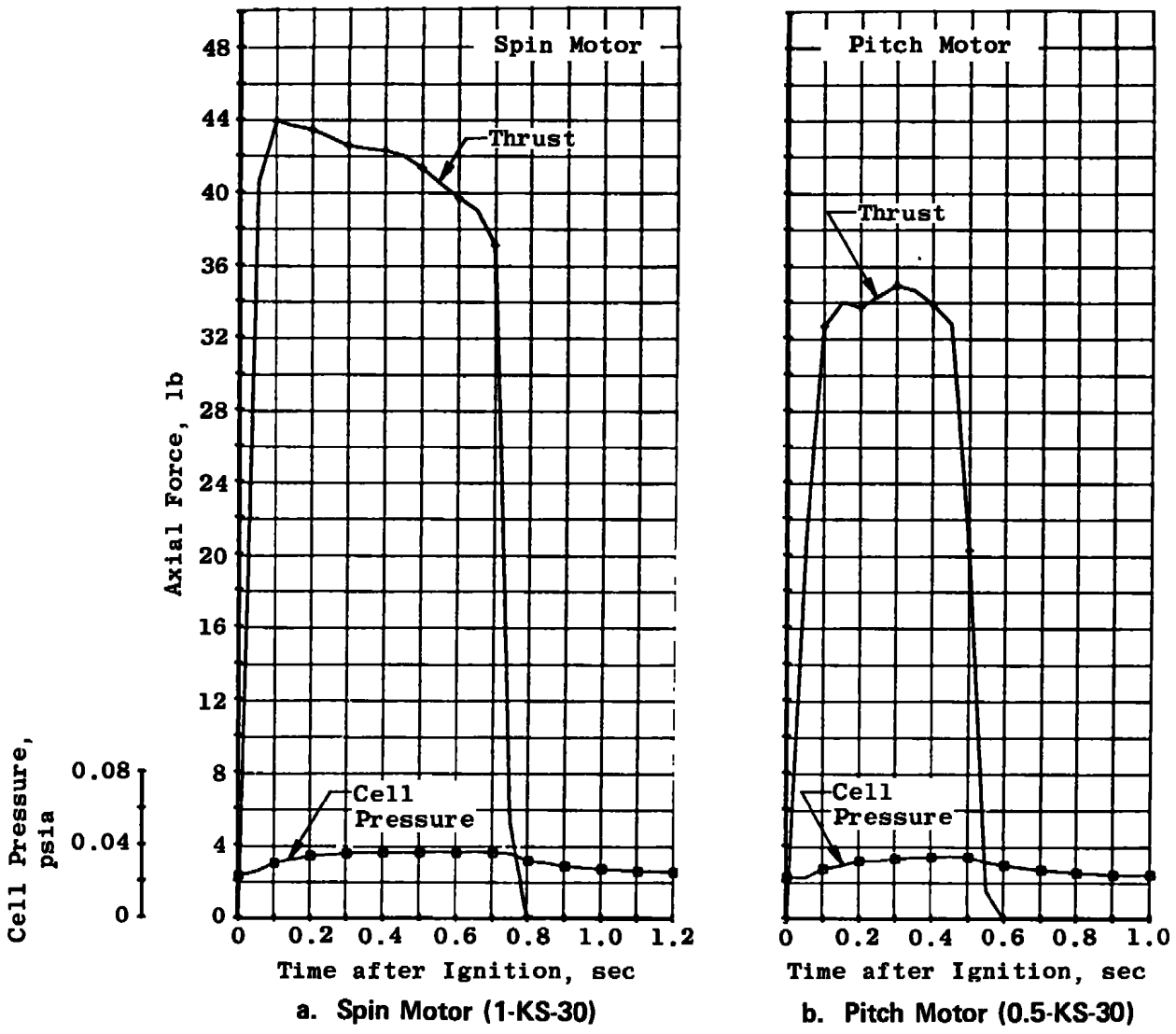


a. Mark 11/11A (P/N 330198-1)

Fig. 10 Variation of Delivered Vacuum Total Impulse with Age for the 0.5-KS-30 Pitch Motors Fired to Date



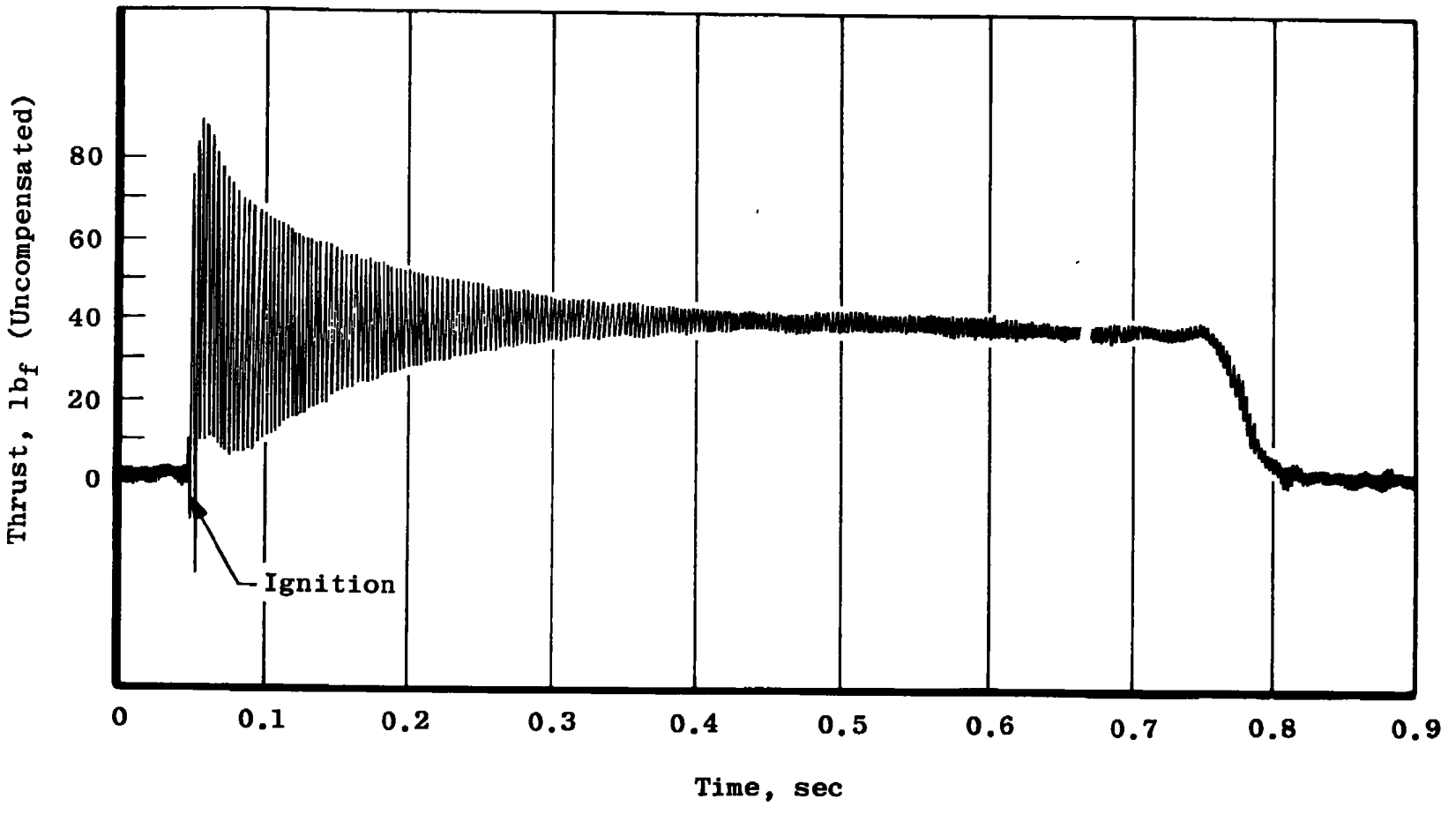
b. Mark 11B/11C (P/N 331121-1)
Fig. 10 Concluded



a. Spin Motor (1-KS-30)

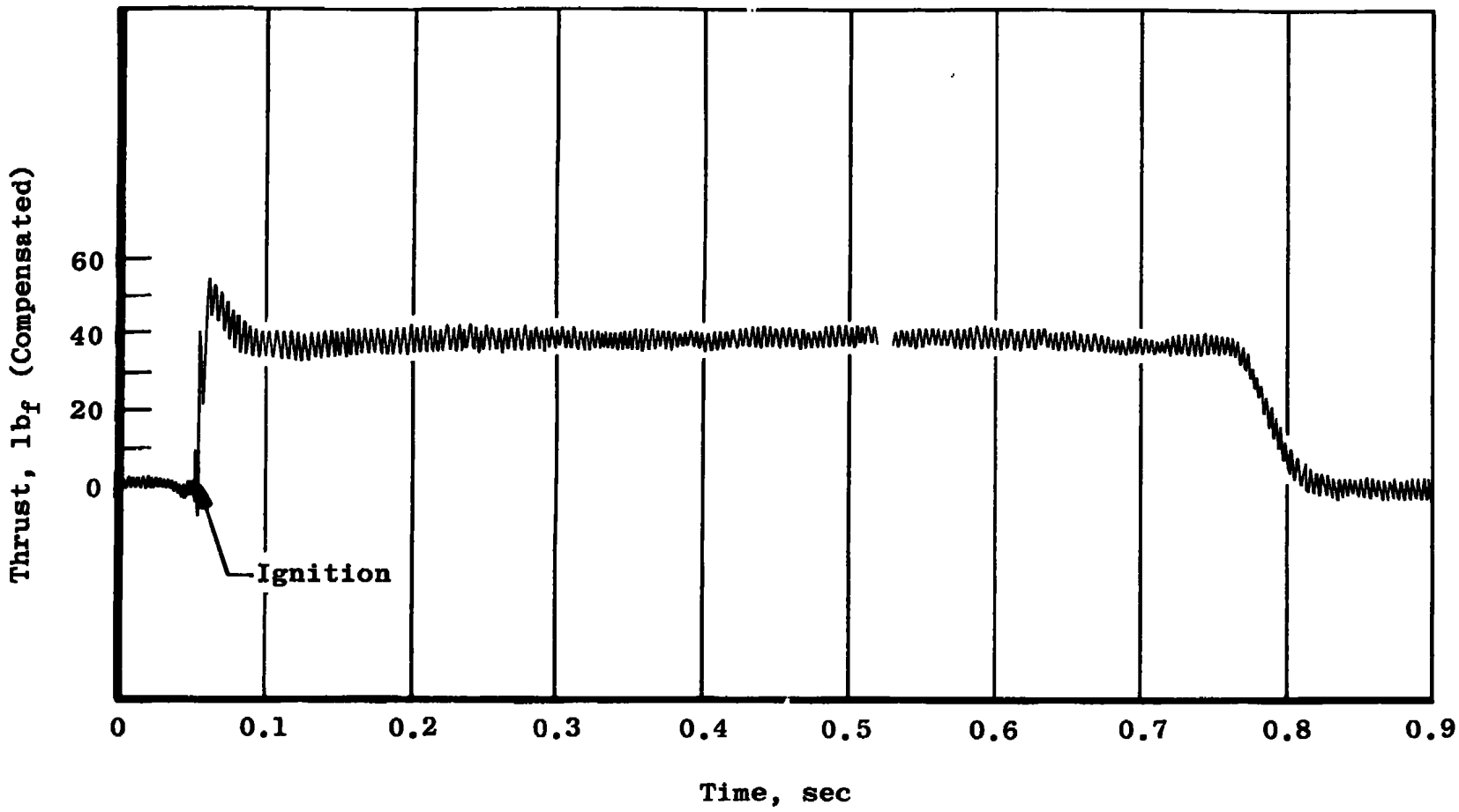
b. Pitch Motor (0.5-KS-30)

Fig. 11 Typical Variations in Indicated Thrust and Cell Pressure during Firing (Based on Data Averaged over 0.050-sec Time Intervals)

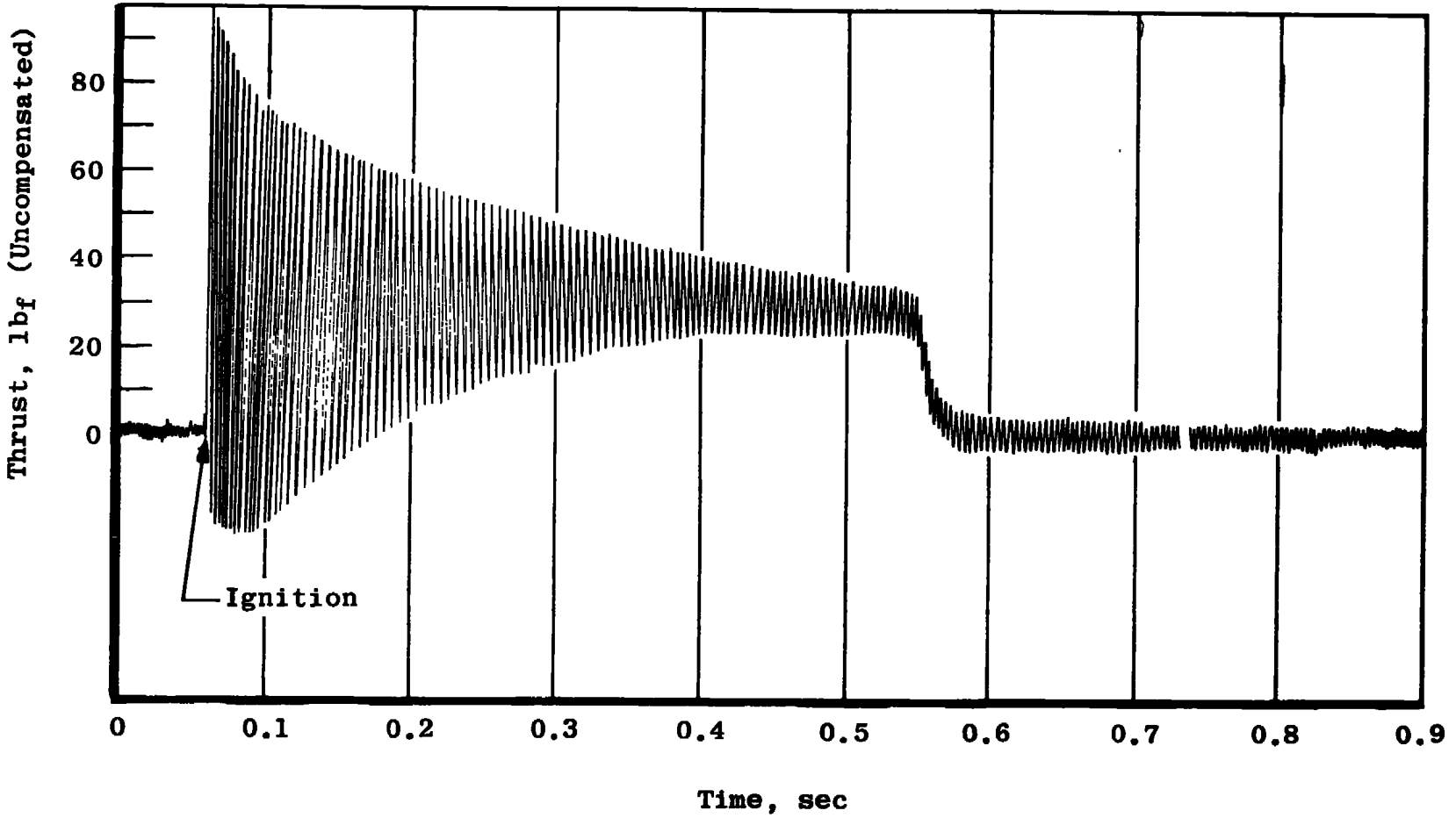


a. Uncompensated Thrust, 1-KS-30 Spin Motor

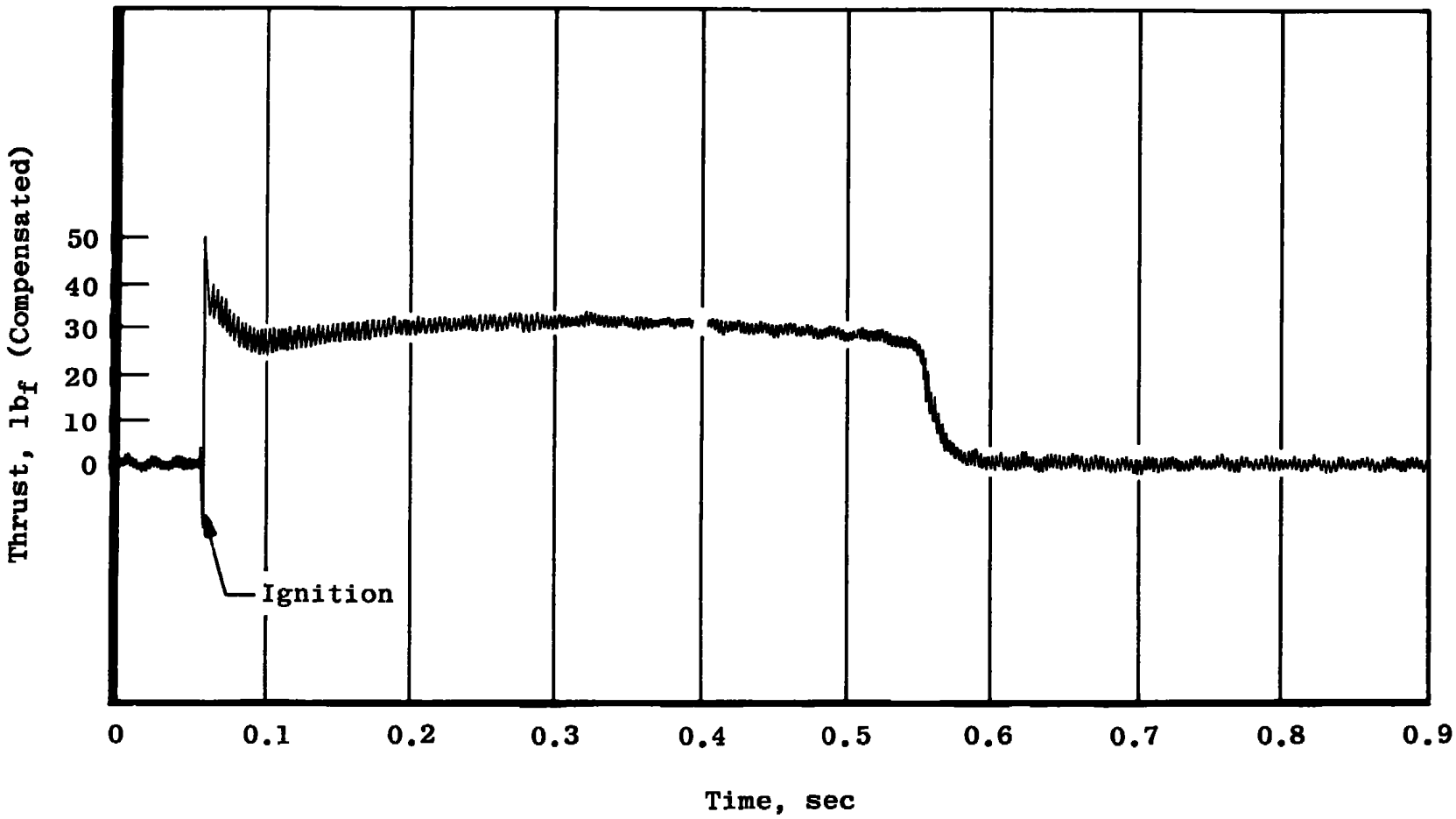
Fig. 12 Variation of Thrust with Time during a Typical Spin and Pitch Motor Firing



b. Compensated Thrust, 1-KS-30 Spin Motor
Fig. 12 Continued



c. Uncompensated Thrust, 0.5-KS-30 Pitch Motor
Fig. 12 Continued



d. Compensated Thrust, 0.5-KS-30 Pitch Motor
Fig. 12 Concluded

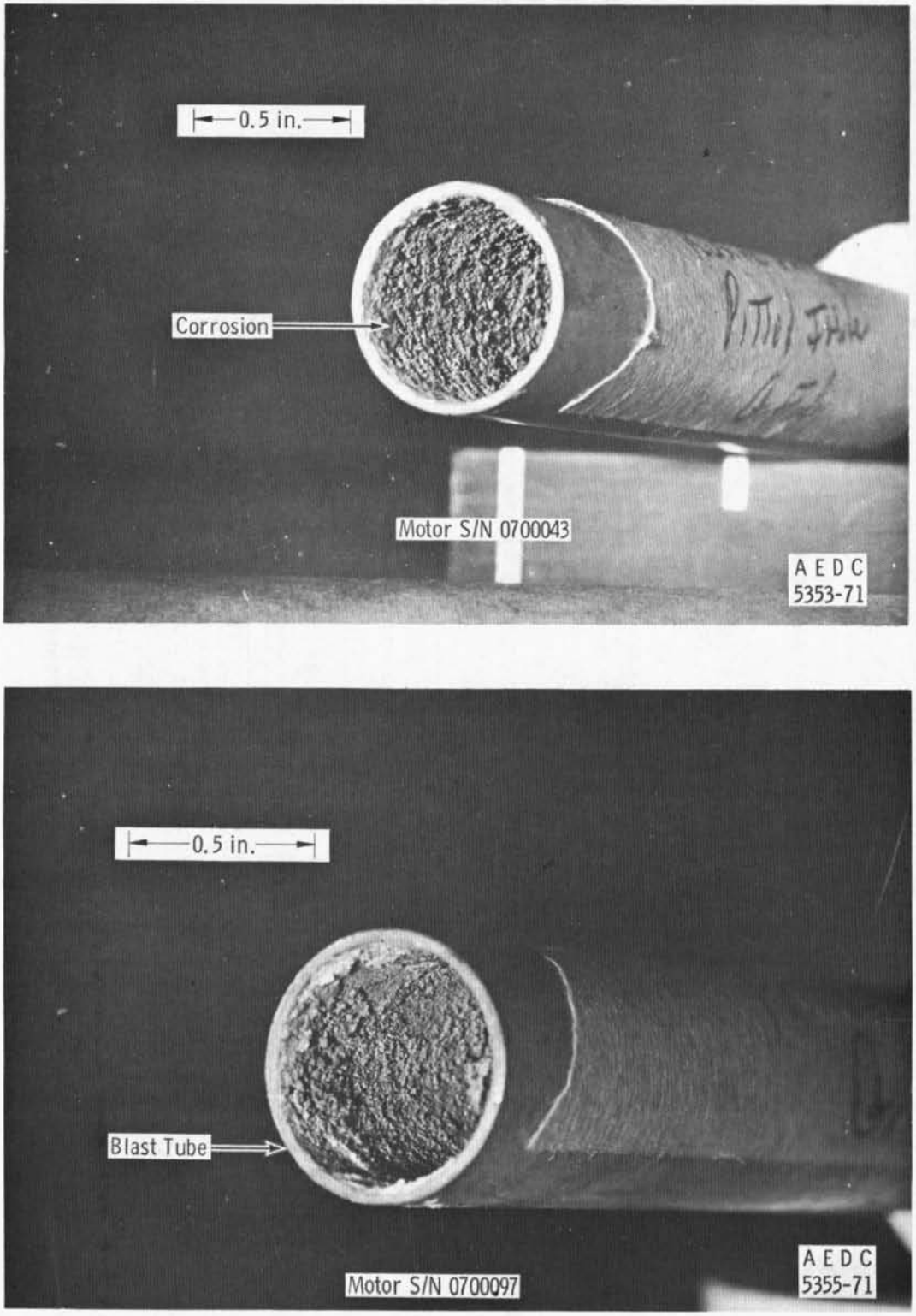


Fig. 13 Prefire Photograph of Blast Tube of Mark 11/11A Spin Motors S/N 0700043 and 0700097

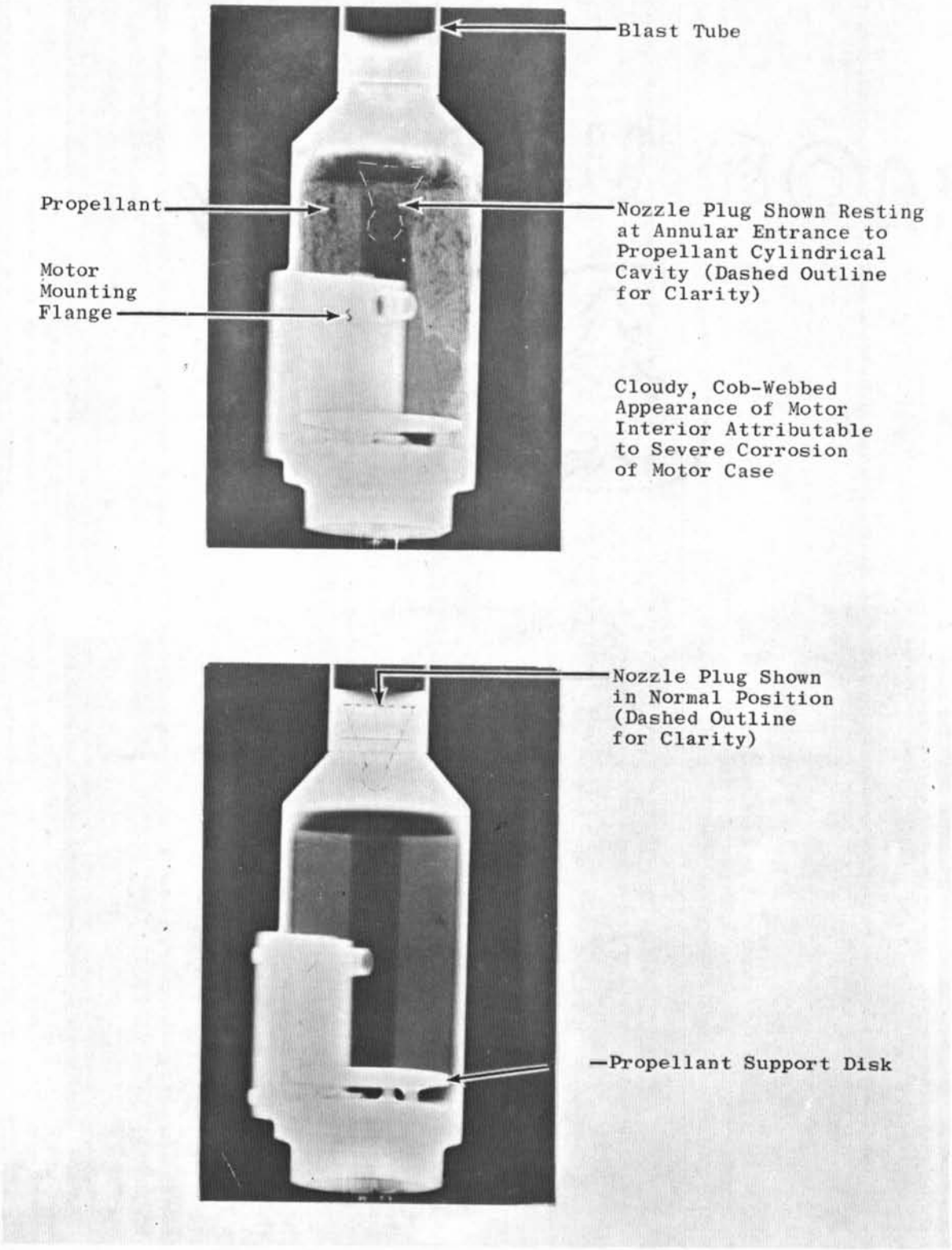
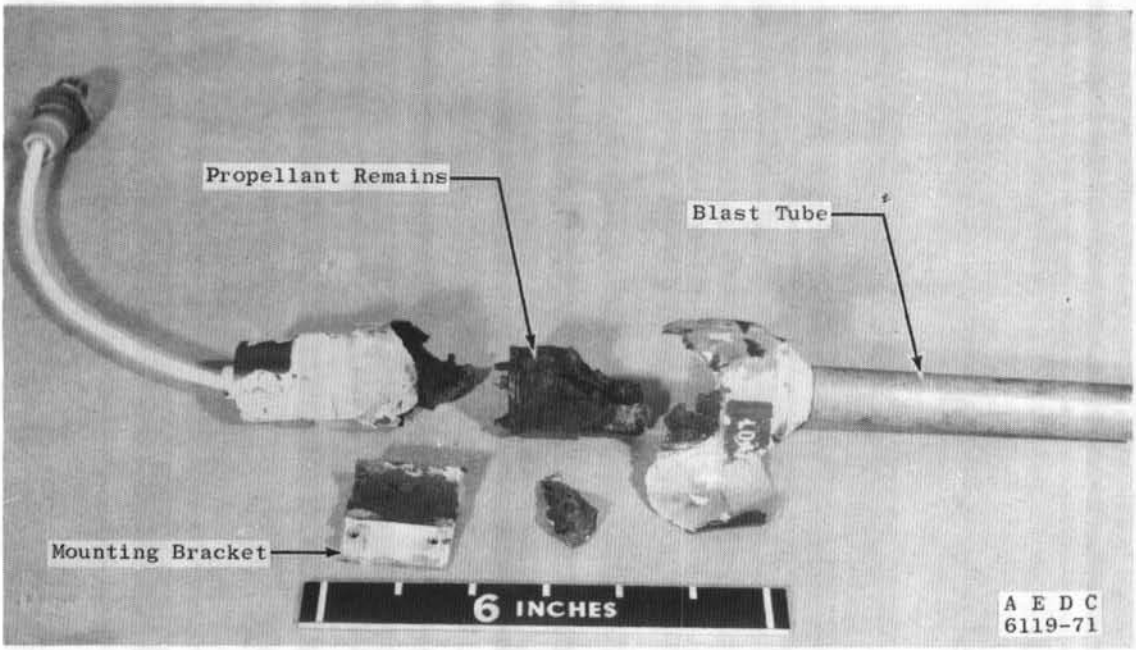
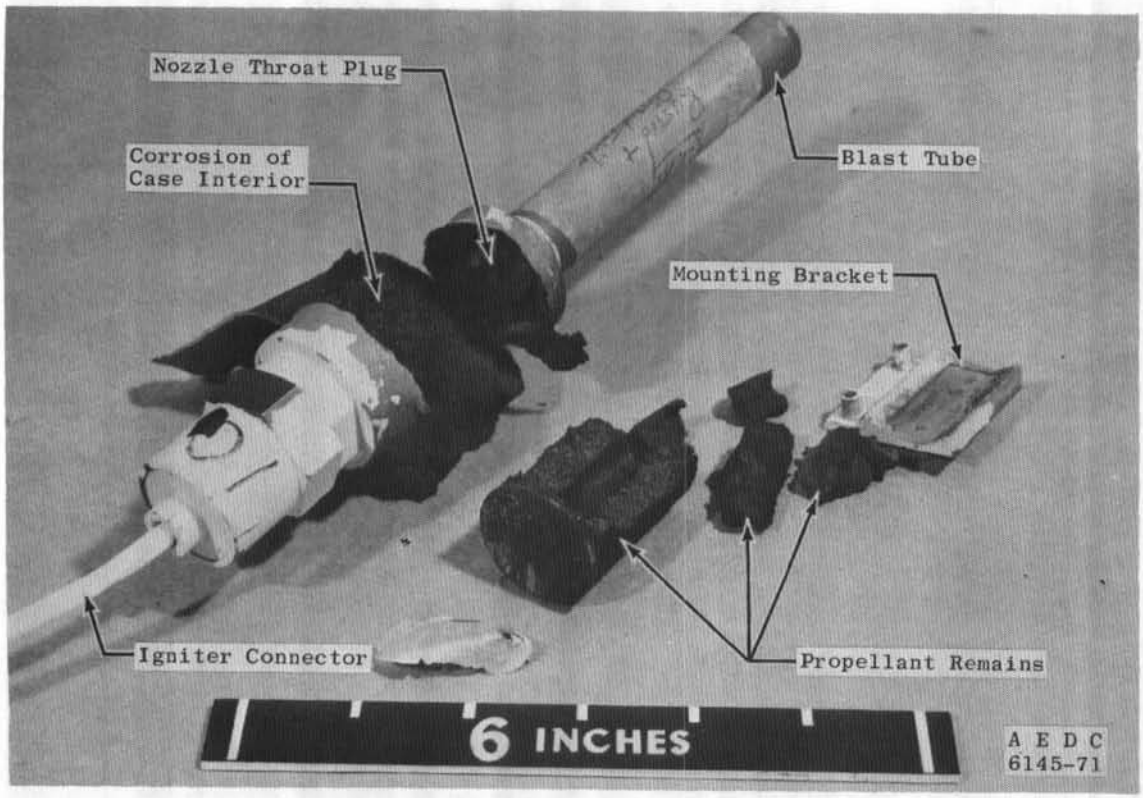


Fig. 14 Radiographs of 1-KS-30 Spin Motor

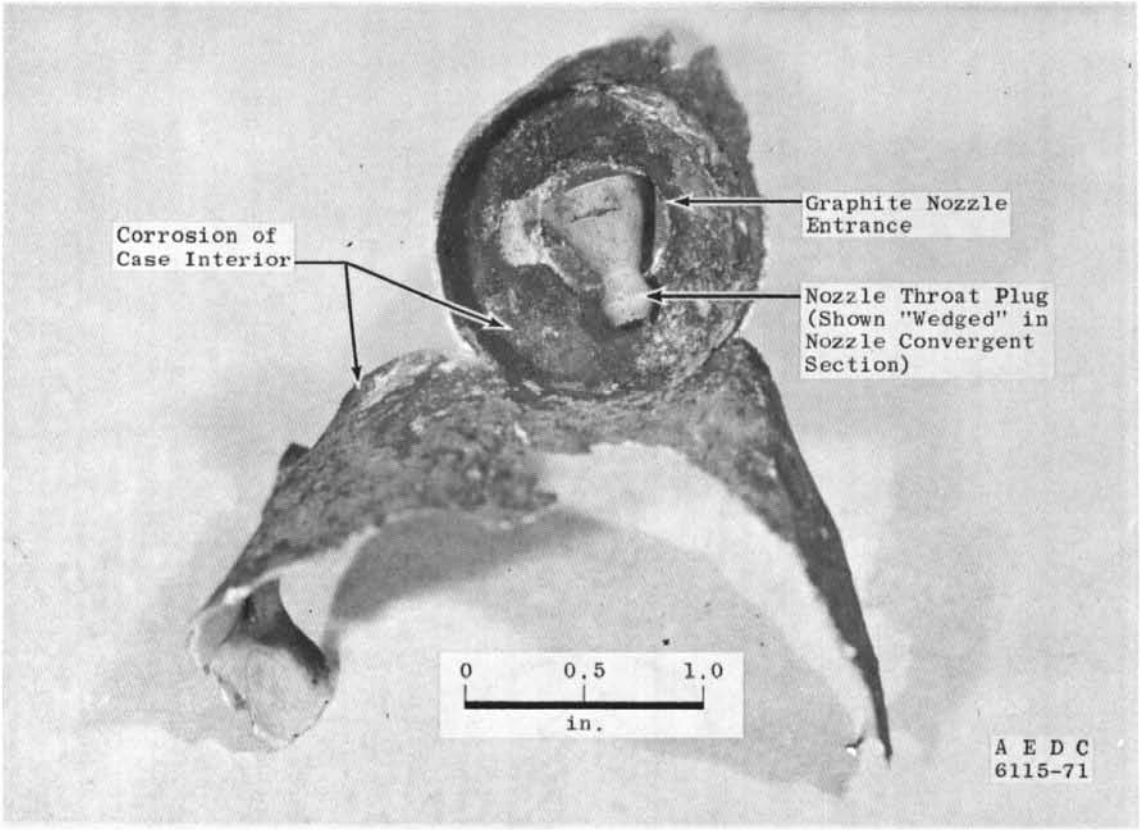


a. Spin Motor S/N 0700043

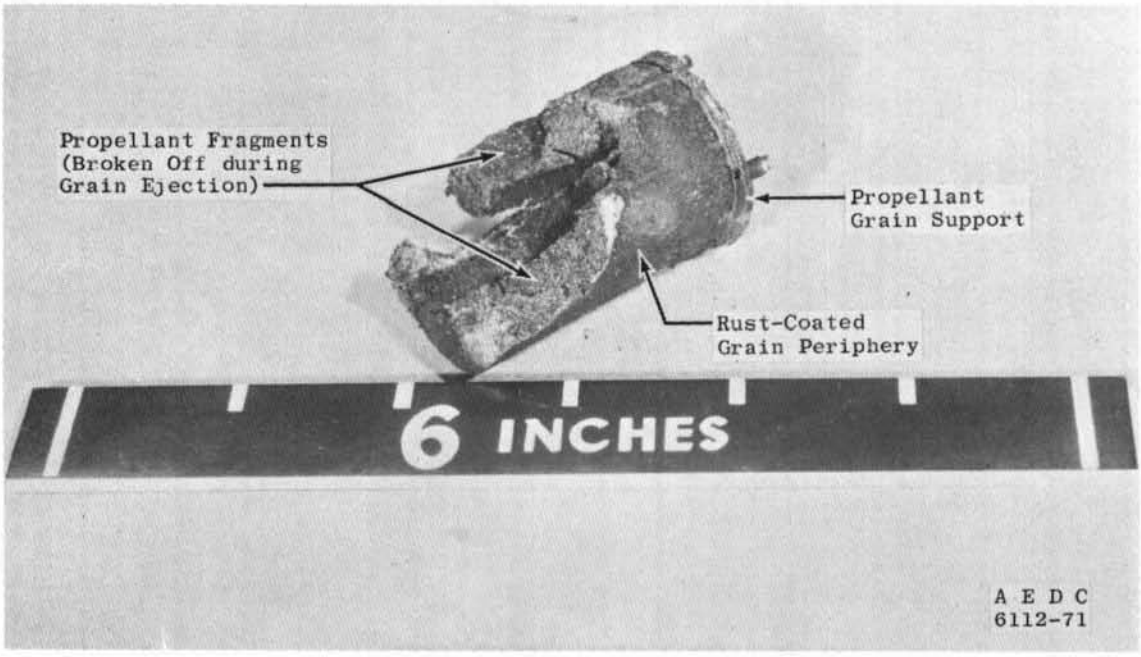


b. Spin Motor S/N 0700097

Fig. 15 Postfire Photograph of Failed Motor



a. Aft Interior Detail



b. Detail of Propellant Grain

Fig. 16 Postfire Photograph of Motor S/N 0700043

TABLE I
INSTRUMENTATION SUMMARY AND MEASUREMENT UNCERTAINTY

Parameter Designation	STEADY-STATE ESTIMATED MEASUREMENT*							Range	Type of Measuring Device	Type of Recording Device	Method of System Calibration
	Precision Index (S)			Bias (B)		Uncertainty $\pm(B + t_{95}S)$					
	Percent of Reading	Unit of Measurement	Degree of Freedom	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement				
Axial Force	±0.25	---	150	±0.1	---	±0.6	-	30 to 45 lbf	Bonded Strain-Gage-Type Force Transducers	Voltage-to-Frequency Converter onto Magnetic Tape	In-Place Application of Deadweights Calibrated in the Standards Laboratory
Total Impulse	±0.18	---	30	±0.1	---	±0.46	---				
Cell Pressure	±6.0	-	150	±5.0	---	±17	---	0.018 to 0.045 psia	Unbonded Strain-Gage Type Pressure Transducers		Resistance Shunt Based on the Standards Laboratory Determination of Transducer Applied Pressure versus Resistance Shunt Equivalent Pressure Relationship
Cell Pressure Integral	±3.5	-	30	±5.0	---	±12	---				
Temperature	---	±0.5°F	90		±3.0°F	---	±4.0°F	70 to 105°F	Iron-Constantan Temperature Transducers	Null Balance Potentiometer Strip Chart Recorder	Millivolt Substitution Based on the NBS Temperature versus Millivolt Tables
Time Interval	---	±0.25 msec	30	---	±0.01 msec	---	±0.51 msec	-	Time Pulse Generator	Photographically Recording Galvanometer Oscillograph	Time Pulse Generator Calibrated in the Standards Laboratory
Weight	---	±0.05 grams	30	---	±0.02 grams	---	±0.12 grams	360 to 510 grams	Beam Balance Scales	Visual Readout	In-Place Application of Deadweights Calibrated in the Standards Laboratory
Squib and Fuse Resistance	---	±0.004 ohms	22	---	±0.002 ohms	---	±0.010 ohms	0.10 to 0.25 ohms	Ohmmeter	Visual Readout	Ohmmeter Calibrated in the Standards Laboratory
Insulation Resistance	Note 1	---	---	±10	---	±10	---	100,000 to 500,000 ohms		---	---

*Reference: CPIA No. 180, "ICRPG Handbook for Estimating the Uncertainty in Measurements made with Liquid Propellant Rocket Engine Systems," April 30, 1969.

Notes No redundant or repeated measurements were made.

TABLE II
PREFIRE AND POSTFIRE RESISTANCE MEASUREMENTS
a. ARC Mark 11B/11C 1-KS-30 Spin Motors (P/N 331120-1)

Motor Type	Specification Limits, ohms	1-KS-30								
Motor Serial Number		0705735	0705736	0705932	0705933	0705732	0706393	0705700	0705566	0706072
Date of Manufacture		10/66	10/66	11/66	11/66	10/66	6/68	5/66	10/66	5/67
Motor Age, months		59	57	56	56	57	37	62	57	50
Test Date		7/14/71	7/14/71	7/14/71	7/15/71	7/15/71	7/15/71	7/21/71	7/21/71	7/21/71
Prefire Ignition System Resistance, ohms										
Pins A to F (Squib No. 1)	0.16 to 0.22	0.21	0.20	0.21	0.21	0.20	0.20	0 19	0 18	0.22
Pins B to C (Squib No. 2)	0.16 to 0.22	0.20	0.20	0.21	0.20	0.20	0 19	0.19	0.19	0.21
Pins D to E (Fuse)	0.02 to 0.10	0.10	0.10	0.09	0.10	0.10	0.04	0.07	0.09	0.02
Shorted Pins AF to Shorted Pins BC	>10 meg	300 meg	250 meg	2,000 meg	1,000 meg	2,000 meg	600 meg	125 meg	250 meg	125 meg
Shorted Pins AF to Shorted Pins DE	>10 meg	900 meg	225 meg	2,000 meg	1,000 meg	2,000 meg	600 meg	125 meg	200 meg	125 meg
Shorted Pins BC to Shorted Pins DE	>10 meg	600 meg	200 meg	2,000 meg	1,000 meg	2,000 meg	800 meg	125 meg	200 meg	125 meg
Prefire Case Insulation Resistance, ohms										
Pins A, B, C, D, E, and F to Motor Case	>10 meg	250 meg	200 meg	1,500 meg	300 meg	*	300 meg	100 meg	200 meg	100 meg

* Pin D to Case 1 18 ohms, Pin E to Case 1 12 ohms

TABLE II (Continued)
b. ARC Mark 11/11A 1-KS-30 Spin Motors (P/N 330130-1)

Motor Type	Specification Limits, ohms	1-KS-30										
Serial Number		0700061	0700099	0700098	0700040	0700156	0700129	0700063	0700060	0700044	0700043	0700097
Date of Manufacture		6/63	6/63	6/63	6/63	*	6/63	6/63	6/63	6/63	6/63	6/63
Motor Age, months		97	97	97	97	*	97	97	97	97	97	97
Test Date		7/28/71	7/28/71	7/28/71	7/28/71	7/28/71	7/28/71	7/29/71	7/29/71	7/26/71	7/29/71	7/30/71
Prefire Ignition System Resistance, ohms												
Pins A to F (Squib No. 1)	0.16 to 0.28	0.19	0.23	0.22	0.23	0.21	0.19	0.20	0.22	0.19	0.21	0.25
Pins B to C (Squib No. 2)	0.16 to 0.28	0.20	0.22	0.21	0.20	0.21	0.21	0.20	0.21	0.22	0.20	0.21
Pins D to E (Fuse)	0.02 to 0.10	0.09	0.10	0.09	0.08	0.10	0.09	0.08	0.08	0.10	0.08	0.09
Shorted Pins AF to Shorted Pins BC	>10,000	150 meg	400 meg	350 meg	300 meg	350 meg	150 meg	300 meg	350 meg	350 meg	300 meg	400 meg
Shorted Pins AF to Shorted Pins DE	>10,000	500 meg	250 meg	400 meg	275 meg	350 meg	150 meg	300 meg	400 meg	250 meg	200 meg	400 meg
Shorted Pins BC to Shorted Pins DE	>10,000	80 meg	500 meg	350 meg	250 meg	350 meg	100 meg	300 meg	450 meg	300 meg	200 meg	500 meg
Prefire Case Insulation Resistance, ohms												
Pins A, B, C, D, E, and F to Motor Case	>10,000	30 meg	200 meg	200 meg	250 meg	**	50 meg	1,000 meg	1,000 meg	175 meg	***	1,000 meg

* Date of Manufacture illegible on identification tag. Igniter was manufactured 8/62.

** Pins AF to case and BC to case: 350 megohms, DE to case: 400 ohms.

*** Pins AF to case and BC to case: 600 megohms; DE to case: between 30 and 100 ohms.

TABLE II (Continued)
c. ARC Mark 11B/11C 0.5-KS-30 Pitch Motors (P/N 331121-1)

Motor Type	Specification Limits, ohms	0.5-KS-30								
Motor Serial Number		0605569	0605894	0605897	0605899	0605901	0605902	0605153	0606073	0606076
Date of Manufacture		10/66	11/66	11/66	11/66	11/66	11/66	5/66	5/67	5/67
Motor Age, months		57	56	56	56	56	56	62	50	50
Test Date		7/8/71	7/8/71	7/8/71	7/14/71	7/14/71	7/14/71	7/24/71	7/24/71	7/24/71
Prefire Ignition System Resistance, ohms										
Pins A to F (Squib No. 1)	0.16 to 0.22	0.21	0.22	0.20	0.22	0.20	0.20	0.20	0.22	0.17
Pins B to C (Squib No. 2)	0.16 to 0.22	0.21	0.21	0.20	0.21	0.21	0.21	0.20	0.22	0.18
Pins D to E (Fuse)	0.02 to 0.10	0.09	0.09	0.10	0.09	0.09	0.09	0.08	0.03	0.03
Shorted Pins AF to Shorted Pins BC	>100 meg	175 meg	200 meg	2,000 meg	1,000 meg	200 meg	400 meg	80 meg	175 meg	200 meg
Shorted Pins AF to Shorted Pins DE	>100 meg	150 meg	200 meg	2,000 meg	1,000 meg	175 meg	400 meg	90 meg	150 meg	200 meg
Shorted Pins BC to Shorted Pins DE	>100 meg	150 meg	200 meg	2,000 meg	1,000 meg	175 meg	400 meg	90 meg	175 meg	200 meg
Prefire Case Insulation Resistance, ohms										
Pins A, B, C, D, E, and F to Motor Case	>100 meg	125 meg	125 meg	600 meg	600 meg	175 meg	200 meg	90 meg	125 meg	200 meg

TABLE II (Concluded)
d. ARC Mark 11/11A 0.5-KS-30 Pitch Motors (P/N 330198-1)

Motor Type	Specification Limits ohms	0.5-KS 30									
Motor Serial Number		0600176	0600198	0600199	0600289	0600291	0600367	0600343	0600344	0600196	0600187	0600233
Date of Manufacture		7/63	1/63	7/63	7/63	8/63	8/63	8/63	8/63	7/63	7/63	7/63
Motor Age, months		96	102	96	96	95	95	95	95	96	96	96
Test Date		7/22/71	7/22/71	7/24/71	7/24/71	7/24/71	7/22/71	7/22/71	7/22/71	7/22/71	7/26/71	7/26/71
Prefire Ignition System Resistance, ohms												
Pins A to F (Squib No. 1)	0.16 to 0.28	0.21	0.19	0.22	0.18	0.19	0.22	0.23	0.23	0.23	0.22	0.26
Pins B to C (Squib No. 2)	0.16 to 0.28	0.20	0.19	0.21	0.20	0.20	0.21	0.23	0.20	0.22	0.23	0.22
Pins D to E (Fuse)	0.02 to 0.10	0.07	0.07	0.10	0.06	0.08	0.08	0.08	0.08	0.08	0.08	0.09
Shorted Pins AF to Shorted Pins BC	>10,000	30 meg	20 meg	300 meg	250 meg	250 meg	35 meg	100 meg	9 meg	25 meg	125 meg	175 meg
Shorted Pins AF to Shorted Pins DE	>10,000	30 meg	25 meg	275 meg	250 meg	225 meg	35 meg	100 meg	9 meg	25 meg	175 meg	175 meg
Shorted Pins BC to Shorted Pins DE	>10,000	30 meg	25 meg	275 meg	250 meg	250 meg	35 meg	100 meg	12 meg	25 meg	150 meg	175 meg
Prefire Case Insulation Resistance, ohms												
Pins A, B, C, D, E, and F to Motor Case	>10,000	40 meg	40 meg	1,000 meg	1,000 meg	100 meg	50 meg	125 meg	20 meg	35 meg	400 meg	175 meg

TABLE III
SUMMARY OF MOTOR PERFORMANCE
a. ARC Mark 11B/11C Spin Motors (P/N 331120-1)

Motor Type	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30
Motor Serial Number	0705735	0705736	0705932	0705933	0705732	0706393	0705700	0705568	0706072
Test Number	07	08	09	10	11	12	13	14	15
Date of Manufacture	10/66	10/66	11/66	11/66	10/66	6/69	5/66	10/66	5/67
Test Date	7/14/71	7/14/71	7/14/71	7/15/71	7/15/71	7/15/71	7/21/71	7/21/71	7/21/71
Motor Age - months	58	57	56	56	57	37	52	57	60
Motor Case Temperature at Ignition, °F	103	102	100	102	101	100	100	99	99
Simulated Altitude at Ignition, ft	146,000	147,000	147,000	146,000	146,000	146,000	144,000	149,000	149,000
Thrust Delay Time (t_d), msec[1]	4	2	2	3	2	3	2	2	2
Ignition Delay Time (t_i), msec[2]	4	2	3	5	2	5	2	2	2
Thrust Action Time (t_{at}), sec[3]	0.713	0.717	0.705	0.683	0.716	0.707	0.693	0.752	0.733
Burn Time (t_b), sec[4]	0.685	0.690	0.678	0.657	0.691	0.678	0.670	0.722	0.705
Full-Duration Burn Time (t_{fb}), sec[5]	0.765	0.770	0.750	0.728	0.780	0.765	0.740	0.795	0.780
Measured Total Impulse (Based on t_{fb}), lbf-sec (Not Weight Corrected)	29 375	29 010	29 246	29 325	25 481	29 301	29 358	28 560	28 555
Number of Channels Averaged	2	-	2	2	2	2	2	2	-
Maximum Deviation from Average, percent	0.11	---	0.02	0.08	0.04	0.00	0.10	0.16	---
Cell Pressure Integral (Based on t_{fb}), psia-sec	0.02726	0.02781	0.02529	0.02722	0.02719	0.02788	0.02881	0.02677	0.02705
Number of Channels Averaged	3	3	3	3	3	3	3	3	3
Maximum Deviation from Average, percent	0.4	0.5	0.9	1.1	0.4	0.4	0.3	0.4	0.5
Average Simulated Altitude during t_{fb}, ft	136,000	137,000	136,000	135,000	136,000	136,000	135,000	138,000	138,000
Vacuum Total Impulse (based on t_{fb}) lbf-sec (Weight Corrected)	29 438	29 073	29 307	29 386	29 342	29.424	29 419	29 024	28,618
Expended Mass (AEDC Measured Prefire and Postfire Weight Difference Including Nozzle Closure), lbm	0.1328	0.1326	0.1328	0.1345	0.1328	0.1332	0.1336	0.1334	0.1339
Manufacturer's Stated Nominal Propellant Weight, lbm	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130
Vacuum Specific Impulse (Based on Weight Corrected Vacuum Total Impulse over t_{fb} and Manufacturer's Stated Nominal Propellant Weight), lbf-sec/lbm	226.4	223.6	225.4	226.0	225.7	226.3	226.3	223.3	220.1

[1]Interval from zero time to time of increase in thrust (where zero time is the time of application of ignition current)

[2]Time interval between zero time and the time that thrust has reached 10 percent of maximum during ignition (excluding ignition spike)

[3]Time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and 10 percent of maximum thrust during tailoff

[4]Time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and the return of thrust to 75 percent of maximum during tailoff

[5]Interval from time of increase in thrust during ignition to time that thrust has decreased to zero during tailoff

TABLE III (Continued)
b. ARC Mark 11/11A Spin Motors (P/N 330130-1)

Motor Type	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30
Motor Serial Number	0700061	0700099	0700038	0700040	0700150	0700129	0700063	0700060	0700044	0700043	0700097
Test Number	31	32	33	34	35	36	37	38	30	39	40
Date of Manufacture	6/63	6/63	6/63	6/63	**	6/63	6/63	6/63	6/63	6/63	6/63
Test Date	7/26/71	7/28/71	7/28/71	7/28/71	7/28/71	7/28/71	7/28/71	7/28/71	7/26/71	7/28/71	7/30/71
Motor Age, months	97	97	97	97	**	97	97	97	97	97	97
Motor Case Temperature at Ignition, °F	74	74	75	74	74	74	74	75	81	75	78
Simulated Altitude at Ignition, ft	145,000	147,000	148,000	147,000	150,000	150,000	146,000	148,000	149,000	148,000	150,000
Thrust Delay Time (t_d), msec[1]	3	2	4	4	4	4	3	4	2	3	4
Ignition Delay Time (t_i), msec[2]	3	2	4	4	4	4	3	4	2	3	4
Thrust Action Time (t_a), sec[3]	0.741	0.727	0.750	0.731	0.753	0.752	0.742	0.741	0.726	*	*
Burn Time (t_b), sec[4]	0.712	0.705	0.737	0.701	0.757	0.721	0.712	0.710	0.696	*	*
Full-Duration Burn Time (t_{fb}), sec[5]	0.800	0.775	0.805	0.770	0.850	0.800	0.800	0.730	0.770	*	*
Measured Total Impulse (Based on t_{fb}), lbf-sec (Not Weight Corrected)	29.227	29.172	28.700	29.209	29.087	28.912	29.001	29.167	29.055	*	*
Number of Channels Averaged	2	2	2	2	2	2	2	2	2	*	*
Maximum Deviation from Average percent	0.22	0.0	0.26	0.12	0.20	0.03	0.19	0.02	0.02	*	*
Cal Pressure Integra. (Based on t_{fb}), psia-sec	0.02742	0.02548	0.02703	0.02638	0.02557	0.026.5	0.02595	0.02604	0.02527	*	*
Number of Channels Averaged	2	2	2	3	3	2	3	3	3	*	*
Maximum Deviation from Average percent	0.2	0.4	0.3	0.4	0.9	0.0	0.8	0.5	0.4	*	*
Average Simulated Altitude during t_{fb}, ft	136,000	137,000	137,000	137,000	30,000	138,000	137,000	137,000	137,000	*	*
Vacuum Total Impulse (Based on t_{fb}) lbf-sec (Weight Corrected)	29.291	29.294	28.764	29.361	29.153	28.975	29.068	29.225	29.117	*	*
Expended Mass (AEDC Measured Prefire and Postfire Weight Difference, Including Nozzle Closure), lbm	0.1352	0.1348	0.1346	0.1349	0.1364	0.1344	0.1356	0.1368	0.1341	0.1045	0.0756
Manufacturer's Stated Nominal Propellant Weight, lbm	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130
Vacuum Specific Impulse (Based on Weight Corrected Vacuum Total Impulse over t_{fb} and Manufacturer's Stated Nominal Propellant Weight), lbf-sec/lbm	225.3	224.9	221.3	225.8	224.3	222.9	223.6	224.8	224.0	*	*

[1]Interval from zero time to time of increase in thrust (where zero time is the time of application of ignition current).

[2]Time interval between zero time and the time that thrust has reached 10 percent of maximum during ignition (excluding ignition spike)

[3]Time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and 10 percent of maximum thrust during tailoff

[4]Time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and the return of thrust to 75 percent of maximum during tailoff

[5]Interval from time of increase in thrust during ignition to time that thrust has decreased to zero during tailoff

*Motor S/N's 0700043 and 0700097 failed during ignition (case ruptured)

**Date of motor manufacture illegible on motor identification tag Igniter was manufactured 6/62

ERRATA

AEDC-TR-71-270, December 1971
(UNCLASSIFIED REPORT)

SIMULATED ALTITUDE PERFORMANCE OF MARK 11 REENTRY VEHICLE SPIN AND PITCH MOTORS HAVING AGES FROM 37 TO 102 MONTHS

R. M. Brooksbank, ARO, Inc.

Arnold Engineering Development Center
Air Force Systems Command
Arnold Air Force Station, Tennessee

Table IIc (page 53) and Table IIIa (page 55) are to be replaced with the corrected tables printed on this sheet.

TABLE II (Continued)
c. ARC Mark 11B/11C 0.5-KS-30 Pitch Motors (P/N 331121-1)

Motor Type	Specification Limits, ohms	0.5-KS-30								
Motor Serial Number		0605569	0605894	0605897	0605899	0605901	0605902	0605153	0606073	0606076
Date of Manufacture		10/66	11/66	11/66	11/66	11/66	11/66	5/66	5/67	5/67
Motor Age, months		57	56	56	56	56	56	62	50	50
Test Date		7/8/71	7/8/71	7/8/71	7/14/71	7/14/71	7/14/71	7/24/71	7/24/71	7/24/71
Prefire Ignition System Resistance, ohms										
Pins A to F (Squib No. 1)	0.16 to 0.22	0.21	0.22	0.20	0.22	0.20	0.20	0.20	0.22	0.17
Pins B to C (Squib No. 2)	0.16 to 0.22	0.21	0.21	0.20	0.21	0.21	0.21	0.20	0.22	0.18
Pins D to E (Fuse)	0.02 to 0.10	0.09	0.09	0.10	0.09	0.09	0.09	0.08	0.03	0.1
Shorted Pins AF to Shorted Pins BC	>10 meg	175 meg	200 meg	2,000 meg	1,000 meg	200 meg	400 meg	80 meg	175 meg	200 meg
Shorted Pins AF to Shorted Pins DE	>10 meg	150 meg	200 meg	2,000 meg	1,000 meg	175 meg	400 meg	90 meg	150 meg	200 meg
Shorted Pins BC to Shorted Pins DE	>10 meg	150 meg	200 meg	2,000 meg	1,000 meg	175 meg	400 meg	90 meg	175 meg	200 meg
Prefire Case Insulation Resistance, ohms										
Pins A, B, C, D, E, and F to Motor Case	>10 meg	125 meg	125 meg	600 meg	600 meg	175 meg	200 meg	90 meg	125 meg	200 meg

TABLE III
SUMMARY OF MOTOR PERFORMANCE
a. ARC Mark 11B/11C Spin Motors (P/N 331120-1)

Motor Type	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30	1-KS-30
Motor Serial Number	0705735	0705736	0705932	0705933	0705732	0706393	0705700	0705566	0706072
Test Number	07	08	09	10	11	12	13	14	15
Date of Manufacture	10/66	10/66	11/66	11/66	10/66	6/68	5/66	10/66	5/67
Test Date	7/14/71	7/14/71	7/14/71	7/15/71	7/15/71	7/15/71	7/21/71	7/21/71	7/21/71
Motor Age, months	59	57	56	56	57	37	62	57	50
Motor Case Temperature at Ignition, °F	103	102	100	102	101	100	100	99	99
Simulated Altitude at Ignition, ft	146,000	147,000	147,000	146,000	146,000	146,000	144,000	149,000	149,000
Thrust Delay Time (t_d), msec[1]	4	2	3	3	2	3	2	2	2
Ignition Delay Time (t_i), msec[2]	4	2	3	3	2	3	2	2	2
Thrust Action Time (t_{at}), sec[3]	0.713	0 717	0.705	0.683	0.716	0.707	0.693	0.752	0 733
Burn Time (t_b), sec[4]	0.685	0.690	0.678	0.657	0.691	0.678	0 670	0.722	0.705
Full-Duration Burn Time (t_{fb}), sec[5]	0.765	0.770	0.750	0.728	0.790	0.765	0.740	0.795	0.780
Measured Total Impulse (Based on t_{fb}), lbf-sec (Not Weight Corrected)	29.375	29.010	29.246	29.325	29.281	29.361	29.358	28.960	28 555
Number of Channels Averaged	2	1	2	2	2	2	2	2	1
Maximum Deviation from Average, percent	0 11	---	0.02	0.08	0.04	0.00	0.10	0 16	---
Cell Pressure Integral (Based on t_{fb}), psia-sec	0.02726	0.02781	0 02529	0.02722	0.02719	0 02788	0.02881	0.02677	0.02705
Number of Channels Averaged	3	3	3	3	3	3	3	3	3
Maximum Deviation from Average, percent	0 4	0.5	0 9	1.1	0.4	0.4	0.3	0 4	0.5
Average Simulated Altitude during t_{fb}, ft	136,000	137,000	136,000	136,000	136,000	136,000	135,000	138,000	138,000
Vacuum Total Impulse (based on t_{fb}) lbf-sec (Weight Corrected)	29.438	29 073	29.307	29.386	29.342	29.424	29.419	29.024	28.618
Expended Mass (AEDC Measured Prefire and Postfire Weight Difference, Including Nozzle Closure), lbm	0.1328	0.1326	0 1326	0 1348	0.1328	0.1332	0.1336	0.1334	0 ,1339
Manufacturer's Stated Nominal Propellant Weight, lbm	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130
Vacuum Specific Impulse (Based on Weight Corrected Vacuum Total Impulse over t_{fb} and Manufacturer's Stated Nominal Propellant Weight), lbf-sec/lbm	226.4	223.6	225.4	226.0	225.7	226.3	226.3	223.3	220.1

[1]Interval from zero time to time of increase in thrust (where zero time is the time of application of ignition current).

[2]Time interval between zero time and the time that thrust has reached 10 percent of maximum during ignition (excluding ignition spike).

[3]Time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and 10 percent of maximum thrust during tailoff.

[4]Time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and the return of thrust to 75 percent of maximum during tailoff.

[5]Interval from time of increase in thrust during ignition to time that thrust has decreased to zero during tailoff.

TABLE III (Continued)
c. ARC Mark 11B/11C Pitch Motor (P/N 331121-1)

Motor Type	0 5-KS-30	0 5-KS-30	C 5-KS-30	0 5-KS-30	0 5-KS-30	0 5-KS-30	0.5-KS-30	C 5-KS-30	0 5-KS-30
Motor Serial Number	0605569	0605804	0605897	0505899	0605901	0605902	0605153	0606073	0606076
Test Number	01	02	03	04	05	06	25	26	27
Date of Manufacture	10/66	11/66	11/66	.1/66	11/66	11/66	5/66	5/67	5/67
Test Date	7/8/71	7/9/71	7/8/71	7/14/71	7/.4/7.	7/14/7.	7/24/71	7/24/71	7/24/71
Motor Age, months	57	58	58	56	56	56	62	50	50
Motor Case Temperature at Ignition, °F	100	99	08	100	100	07	97	97	97
Simulated Altitude at Ignition, ft	151 000	149, 00C	150 000	148, 000	140, 000	145 000	148, 000	148 000	147, 000
Thrust Delay Time (t_d), msec[1]	4	3	2	5	5	5	1	2	2
Ignition Delay Time (t_i), msec[2]	4	3	2	5	5	5	1	2	2
Thrust Action Time (t_{at}), sec[3]	0 466	0 468	0 474	0, 468	0 472	0 478	0 467	0, 478	0 479
Burn Time (t_b), sec[4]	0, 419	0 422	0 423	0 4.7	0 426	0, 430	C 432	0 437	C 44.
Full Duration Burn Time (t_{fb}) sec[5]	0, 494	0 513	0 512	0 5.C	0 507	0 505	C 530	0, 515	0 530
Measured Total Impulse (Based on t_{fb}), lbf-sec (Not Weight Corrected)	15 094	15 710	15 620	15 698	15 644	15 615	15 732	15 631	15 682
Number of Channels Averaged	2	1	2	2	2	2	2	2	2
Maximum Deviation from Average, percent	0, 01	---	0 00	0 10	C 03	0 C1	0 00	0 00	0 00
Cell Pressure Integral (Based on t_{fb}), psia-sec	0 01576	0 01530	0 01576	0 01575	0 01738	0 01806	0 01667	0 01634	0 01693
Number of Channels Averaged	3	3	3	3	3	3	3	3	3
Maximum Deviation from Average percent	1 2	0 7	C 5	0, 7	0 5	0 3	0 3	0, 4	0, 4
Average Simulated Altitude during t_{fb}, ft	141, 000	141, 000	141, 000	141, 000	138, 000	137, 000	139, 000	140 000	139, 000
Vacuum Total Impulse (Based on t_{fb}) lbf-sec (Weight Corrected)	15 728	15 735	15, 645	15 722	15 870	15 64C	15 758	15 556	15 708
Expended Mass (AEDC Measured Prefire and Postfire Weight Difference, Including Nozzle Closure), lbm	0, 0699	0 0714	0 0718	0 0718	0 0719	0 0721	0 0716	0 0711	0 0716
Manufacturer's Stated Nominal Propellant Weight, lbm	0 059	0 C69	0 069	0 069	0 C69	0 069	0 069	0 069	C 069
Vacuum Specific Impulse (Based on Weight Corrected Vacuum Total Impulse over t_{fb} and Manufacturer's Stated Nominal Propellant Weight), lbf-sec/lbm	227 8	228 0	225 7	227 9	227 1	226, 7	228 4	225 0	227 6

[1]Interval from zero time to time of increase in thrust (where zero time is the time of application of ignition current)

[2]Time interval between zero time and the time that thrust has reached 10 percent of maximum during ignition (excluding ignition spike)

[3]Time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and 10 percent of maximum thrust during tailoff

[4]Time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and the return of thrust to 75 percent of maximum during tailoff

[5]Interval from time of increase in thrust during ignition to time that thrust had decreased to zero during tailoff

TABLE III (Concluded)
d. ARC Mark 11/11A Pitch Motor (P/N 330198-1)

Motor Type	C 5-KS-30	C 5-KS-30	C 5-KS-30	C 5-KS-30	C 5-KS-30	C 5-KS-30	C 5-KS-30	C 5-KS-30	C 5-KS-30	C 5-KS-30	C 5-KS-30	C 5-KS-30
Motor Serial Number	0600176	0600198	0600199	0600289	0600291	0600367	0600343	0600344	0600196	0600187	0600233	
Test Number	20	21	22	23	24	16	17	18	19	28	29	
Date of Manufacture	7/63	7/63	7/63	7/63	8/63	8/63	8/63	8/63	7/63	7/63	7/63	
Test Date	7/22/71	7/22/71	7/24/71	7/24/71	7/24/71	7/22/71	7/22/71	7/22/71	7/22/71	7/22/71	7/26/71	7/26/71
Motor Age, months	96	102	96	95	95	95	95	95	96	96	96	96
Motor Case Temperature at Ignition, °F	76	77	80	80	80	73	73	74	75	79	79	79
Simulated Altitude at Ignition, ft	95 000	48, 000	145 000	48, 000	145 000	48, 000	145 000	48, 000	147 000	147, 000	148, 000	
Thrust Delay Time (t_d), msec[1]	3	4	1	2	2	3	2	2	2	3	4	
Ignition Delay Time (t_i), msec[2]	3	4	1	2	2	3	2	2	2	3	4	
Thrust Action Time (t_a), sec[3]	0 495	0 507	0 489	0 488	0 496	0 494	0 510	0 487	0 505	0 488	0 501	
Burn Time (t_b), sec[4]	0 468	0 475	0 459	0 459	0 461	0 467	0 465	0 47-	0 471	0 466	0 464	
Full-Duration Burn Time (t_{fb}), sec[5]	0 525	0 540	0 540	0 505	0, 540	0, 530	0 540	0 515	0 5..	0, 530	0 530	
Measured Total Impulse (Based on t_{fb}), lbf-sec (Not Weight Corrected)	15 561	15 672	15 569	15 631	15 653	15 633	15 548	15, 400	15 575	15 614	15 626	
Number of Channels Averaged	2	1	2	2	2	2	2	1	2	2	2	
Maximum Deviation from Average percent	0 21	---	0, 18	0 09	0 02	0, 24	0 18	---	0, 06	0 45	0 02	
Cell Pressure Integral (Based on t_{fb}), psia-sec	0 13660	0 01653	0 01725	0, 01749	0 01688	0 01635	0 01749	0 01776	0 01807	0 01833	0 01687	
Number of Channels Averaged	2	4	3	3	3	3	3	3	3	2	3	
Maximum Deviation from Average percent	0 2	1 3	0, 8	0 2	0 5	0 5	0 C	0, 2	0 2	0 0	0 4	
Average Simulated Altitude during t_{fb}, ft	94, 000	139, 000	141, 000	140, 000	141, 000	139, 000	135, 000	140, 000	139 000	139, 000	139, 000	
Vacuum Total Impulse (Based on t_{fb}), lbf-sec (Weight Corrected)	15, 54C	15 698	15 536	15, 656	15 662	15 688	15 574	15, 425	15 800	15, 64C	15 652	
Expended Mass (AEDC Measured Prefire and Postfire Weight Difference, Including Nozzle Closure), lbm	0 0729	0 0739	0 0718	0 0718	0 0727	0 0723	0 0715	0 0721	0 0729	0 0714	0, 0714	
Manufacturer's Stated Nominal Propellant Weight, lbm	0, 059	0 C89	C 069	0 069	0 069	0 069	C 069	0 069	0 069	0 059	0, 069	
Vacuum Specific Impulse (Based on Weight Corrected Vacuum Total Impulse over t_{fb} and Manufacturer's Stated Nominal Propellant Weight), lbf-sec/lbm	226 7	227 5	226 0	226 9	227 2	226 9	225 7	223 8	226 1	226 7	226 8	

[1]Interval from zero time to time of increase in thrust (where zero time is the time of application of ignition current)

[2]Time interval between zero time and the time that thrust has reached 10 percent of maximum during ignition (excluding ignition spike)

[3]Time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and 10 percent of maximum thrust during tailoff

[4]Time interval between 10 percent of maximum thrust during ignition (excluding ignition spike) and the return of thrust to 75 percent of maximum during tailoff

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13 ABSTRACT

Twenty Atlantic Research Corporation (ARC) pitch motors (0.5-KS-30)(9 of P/N 331121-1 and 11 of P/N 330198-1) and twenty ARC spin motors (1-KS-30)(9 of P/N 331120-1 and 11 of P/N 330130-1) were subjected to prescribed nondestructive sinusoidal vibration, temperature cycling (from -35 to +125°F), and electrical resistance measurements and tested at pressure altitudes ranging from 135,000 to 141,000 ft to investigate the possibility of extending the service life of the motors. The ages of the motors ranged from 37 to 102 months. Two of the spin motors failed at ignition, resulting in case rupture and ejection of the propellant grain.

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